I.

REPORTS

OF

MEDICAL INSPECTORS

OF THE

LOCAL GOVERNMENT BOARD.

No. 226.

DR. R. J. REECE'S REPORT TO THE LOCAL GOVERNMENT BOARD ON THE EPIDEMIC OF ENTERIC FEVER IN THE CITY OF LINCOLN, 1904-5.

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Dr. R. J. Reece's Report to the Local Government Board on the Epidemic of Enteric Fever in the City of Lincoln, 1904-5.

W. H. POWER.
Medical Officer,
3rd February, 1906.

I.—Introduction.

On January 26th, 1905, a deputation from the Town Council of Lincoln attended at Whitehall, and represented that during recent weeks cases of enteric fever had become increasingly numerous, and that locally it was apprehended that a serious outbreak of the disease was impending. They accordingly sought the advice and assistance of the Local Government Board. They added that Dr. Charles Harrison, their Medical Officer of Health, was confined to his house through an attack of influenza.

The Board asked that certain further information be procured and sent to Whitehall by Saturday, January 28th. This request was complied with, and on January 30th I received instructions to proceed to Lincoln to investigate the circumstances under which the outbreak was occurring.

On January 31st I had an interview at Lincoln with the Mayor, Alderman Wyatt; the Chairman of the Health Committee, Mr. Footman; the Deputy Town Clerk, Mr. W. T. Page, Junior; the City Engineer, Mr. R. McBrair; the Inspector of Nuisances, Mr. Curtin; the Water Engineer, Mr. Teague; and, after this meeting and at his residence, with Dr. Harrison, who was still too ill to leave his house.

It was clear from the data supplied to the Board by the City Council, and from what I learned at this first interview, that Lincoln was experiencing a severe epidemic of enteric fever. Also it appeared that cases of the disease had occurred in the small adjoining Urban District of Bracebridge, and in a portion, New Boultham, of the parish of Boultham, in the Branston Rural District. My investigations accordingly were extended so as to include these two localities in the inquiry.

The Cathedral City of Lincoln, the capital town of Lincolnshire, is situated on the banks of the River Witham and lies in the centre of an agricultural district. It has a largely attended market. There are corn

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mills and tanneries in the City, which also has a large and increasing industry in the manufacture of agricultural implements and in trades allied to this manufacture.

The Great Northern, the Great Eastern, the Midland, and the Great Central Railways run into the City. There is communication with Gainsborough and the Yorkshire towns by water through the Foss Dyke which joins the River Trent, and with Boston and the Wash by the River Witham.

The City is annually visited by a large number of tourists.

Lincoln is an assize town ; the Prison is situated in the eastern part of the City ; on the high ground to the north-west, are the Barracks, the depôt of the Lincolnshire Regiment. Other institutions within the City are, the County Hospital for general diseases ; the Workhouse ; and "The Lawn," a large private lunatic asylum.

The City of Lincoln consists of two portions, one built on the top and southern slopes of a hill, which rises abruptly from the plain of the Wold, and a larger and more populous portion which is built partly on low-lying ground situated mainly on the southern side of the River Witham. The terms "up hill" or "above hill" and "down hill" or "below hill," are used in Lincoln to describe respectively the neighbourhoods on the high ground near to and around the cathedral, and those on the lower ground to the south of it. The lower part of the town, the surface of which is only 25 feet above ordnance datum, is built upon alluvial sand and gravel. The higher portions of the town, ranging from 100 to 225 feet above ordnance datum, stand on clay overlying the Oolite.

Lincoln is one of the old fortified cities, having a castle, as well as the cathedral, within its walls. Round the castle and cathedral are grouped at once the best and some of the worst houses of the City. It is here that houses are old, and streets some of them narrow and crooked, many houses being built irregularly, with the result of impeding lighting and ventilation. Beside the many old dwellings and small cottage property on the hill, a similar class of dwelling is seen in the narrow courts, alleys and causeways leading from the river in Waterside North, and Waterside South. The River Witham flows with a wide curve through the town, and it is connected with a fresh-water dyke (Sincil Dyke), which starts from the river opposite the waterworks, and, after flowing through the City, joins this stream again lower down its course, some miles below Lincoln.

Liability of the district to floods.—The River Witham in passing through an agricultural district is joined by a tributary, the River Brant, some five miles above Lincoln, and by numerous small tributary streams and dykes and land drains before reaching the City. These drains and streams carry off the natural drainage of the land ; during heavy rains they become overfilled, and at times the river floods the lower parts of Lincoln. The last time that this happened was on 17th August, 1904, when $1\frac{1}{4}$ inches of rain fell between 9 a.m. and 8 p.m., with the result that some of the yards at the backs of the houses in Bridge Street, East Side, were flooded to within 5 ft. or 6 ft. of the back doors ; meanwhile the storm water rose in the sewers and escaped through the sewer gullies in the yards.

The Bracebridge Urban District, formed by the County Council on the 1st April, 1898, is an extension of the City of Lincoln to the south. It has a population of 17–1800 persons. The houses, mainly of like class with the artizans' dwellings found in Lincoln, are built on each side of a main road, which has branch streets leading from it. On the one side the terraces of houses in these branch streets extend to the River Witham and on the other towards high ground.

The Branston Rural District comprises among many others the parish of Boultham, which has a portion, New Boultham, with a population of 800–1,000 persons, adjoining Lincoln on its south-western boundary. Here artizans' dwellings, similar to those of the City, have been built, and this collection of houses practically forms a suburb of Lincoln.

On the high land to the south-east of Lincoln, also in the Branston Rural District, is the Bracebridge District Pauper Asylum, which receives pauper lunatics from the County Council areas of Lindsey and Holland, the City of Lincoln, and the County Borough of Grimsby.

The City of Lincoln, Bracebridge Urban, and New Boultham, the part of the Boultham Parish referred to, form an inhabited area which is supplied with water from the Lincoln Corporation Waterworks, under the Lincoln Waterworks Acts of 1846 and 1871; and the sewers of the two smaller districts are connected with the sewerage system of Lincoln. The Bracebridge District Asylum is also supplied with the Corporation water, and the amount received there, as determined by metre, averages 36,000 gallons a day.

The following table deals with the area, population, number of inhabited houses, and with the rateable value of the districts to which the epidemic of enteric fever has been practically limited.

TABLE I. showing the area, population, rateable value, number of inhabited houses in the City of Lincoln, and in the Bracebridge Urban District, at the Census of 1901; together with like data approximately estimated for New Boultham, a part of the Boultham Parish of the Branston Rural District.

Sanitary District.	Area in Acres.	Population Census. 1901.	Rateable Value.	Number of Inhabited Houses.
City of Lincoln	3,755	48,784	£203,788	10,856
Bracebridge Urban District...	349	1,752	£4,085	370
Branston R. D.	6	885*	—	177
Part of the Parish of Boultham, "New Boultham."†				

* As estimated.

† Area bounded on the east by the City of Lincoln, on the west by the Midland Railway Company's Line, on the south by the banks of the main land drain.

A third district, the Welton Rural District, adjoins Lincoln, but it does not receive water supply from, nor does it share in the system of sewerage of Lincoln.

HISTORY, TO 1904, OF ENTERIC FEVER IN THE INVADED DISTRICTS.

The City of Lincoln forms part of the Lincoln Home Registration Sub-District of the Lincoln Registration District. Statistics from the Registrar-General's Reports are not, therefore, available for the City except in certain particulars.

The following table (Table II.) gives the population of the City since 1861 at the census years, with the estimated population in other years; and the number of deaths from enteric fever, with death rates per 1,000 inhabitants, for the years 1867–1904. The number of deaths from enteric fever has been extracted from the Annual Reports of the Medical Officer of Health.

TABLE II.—Showing for the City of Lincoln the population at the census years and the estimated population in other years, together with the number of deaths, and the death-rate per 1,000, from enteric fever for the years 1867–1904 inclusive.

Year.	Population.	Enteric Fever.				
		City of Lincoln.			England and Wales.	
		No. of Deaths.	Death-rate per 1,000.		Death-rate per 1,000.	
1861 Census	**20,999**	—	—	**Average of Rates**	—	**Average of Rates**
1867	24,437	4	·16		—	
1868	25,038	11	·43		—	
1869	25,653	23	·89		·39	
1870	26,283	26	·98		·38	
1871 Census	**26,766**	—	—		—	
1871	26,784	22	·82		·37	
1872	27,900	11	·39		·37	
1873	28,843	19	·66		·37	
1874	29,817	13	·43		·37	
1875	30,824	10	·32		·37	
1876	31,866	13	·40	**·51**	·30	**·32**
1877	32,942	15	·45		·27	
1878	34,055	10	·29		·30	
1879	35,205	36	1·02		·23	
1880	36,394	13	·35		·26	
1881 Census	**37,313**	—	—		—	
1881	37,412	8	·21		·21	
1882	37,811	12	·31		·22	
1883	38,214	8	·20		·22	
1884	38,622	7	·18		·23	
1885	39,034	10	·25		·17	
1886	39,451	8	·20	**·21**	·18	**·19**
1887	39,872	5	·12		·18	
1888	40,297	11	·27		·17	
1889	40,727	11	·27		·17	
1890	41,161	7	·11		·17	
1891 Census	**41,491**	—	—		—	
1891	41,659	2	·04		·16	
1892	42,339	6	·14		·13	
1893	43,030	12	·27		·22	
1894	43,732	7	·16		·15	
1895	44,446	6	·13		·17	
1896	45,172	11	·24	**·15**	·16	**·16**
1897	45,909	6	·13		·15	
1898	46,659	7	·15		·18	
1899	47,420	7	·14		·19	
1900	48,195	6	·12		·17	
1901 Census	**48,784**	—	—		—	
1901	48,981	5	·10		·15	
1902	49,782	3	·06	**·07**	·12	
1903	50,594	4	·07		·10	
1904	51,419	3	·06		—	

This table shows that in successive decennia the death-rates from enteric fever for Lincoln and for England and Wales* have continuously diminished; and that the Lincoln rate, which was aforetime above 50 per cent. in excess of that of England and Wales, has in recent years remained much below that of the rest of the country.

In relation with the marked diminution of enteric fever in Lincoln in the early eighties, and the progressive decrease of this disease in following years, it may be noted that the filtration area at the waterworks was largely increased in 1878 and again in 1884; that a sewerage system was provided for the City in the years 1877–80; and that systematic abolition of vault privies has been going on since the introduction of the sewerage system.

The Corporation of Lincoln did not take advantage of the powers conferred on them by the Infectious Diseases (Notification) Act, 1889, to make the notification of infectious diseases compulsory within the area of their jurisdiction, though they were advised to do so by their Medical Officer of Health; thus such notification was not operative in Lincoln until the Infectious Diseases (Notification) Act, 1899, made the notification of infectious diseases compulsory in all districts.

For the five years 1900–1904 data are forthcoming enabling a comparison in the above and other particulars of Lincoln with the Registrar-General's groups of towns. The statistics thus obtained (Table III.) are, except in the matter of "all causes at all ages mortality," wholly in favour of Lincoln.

The following table (Table III.) gives year by year 1900–1904 for Lincoln City the population; the "all ages," "infantile," and "zymotic" death-rates; the number of deaths from enteric fever, the death-rate therefrom; and the number of notifications and the attack rate by the disease. Corresponding rates, so far as they are available, for the Registrar-General's group of towns (which includes Lincoln) are given for comparison.†

Year.	Population.	Death-rate.			Enteric Fever.			
		All Causes at all Ages.	Infantile per 1,000 Births.	Zymotic.	No. of Deaths.	Death-rate.	No. of Notifications.	Attack Rate.
Lincoln City { 1891 Census	41,491							
Lincoln City { 1900, estimated	48,195	19·1	152	1·78	6	·12	19	·39
67 Towns	*4,083,236*	*18·1*	*166*	*2·26*	—	*·19*	—	—
Lincoln City { 1901 Census	48,784							
Lincoln City { 1901, estimated	48,981	16·0	144	1·79	6	·10	15	·30
67 Towns	*4,090,362*	*17·1*	*163*	*2·24*	—	*·18*	—	—
Lincoln City, 1902, estimated	49,782	15·5	117	1·02	3	·06	12	·24
103 Towns	*3,642,185*	*15·3*	*155*	*1·53*	—	*·13*	—	—
Lincoln City, 1903, estimated	50,594	15·8	140	1·42	4	·07	32	·63
103 Towns	*3,706,326*	*14·6*	*135*	*1·41*	—	*·11*	—	—
Lincoln City, 1904, estimated	51,419	15·9	163	1·78	3	.06	17	·33
147 Towns	*4,693,630*	*15·6*	*154*	*2·03*	—	*·10*	—	—

* The death-rate from enteric fever for England and Wales is given by the Registrar-General only from 1869 onwards.

† In the Registrar-General's Reports towns are grouped according to their population.

Registrar-General's Group of Towns, which includes Lincoln.—Consideration of the above data shows that Lincoln compares not unfavourably with the aggregate figures of the towns to which it is most nearly allied as regards population.

Enteric fever in the *Bracebridge Urban District.*—Since its formation in 1898, and prior to the year 1904, only two cases of enteric fever have been notified in this small district, which, as has been said, has a population under 2,000 : one in 1900, and one, an imported case, in 1899. In 1904, prior to the present epidemic, only one enteric fever case was notified, viz., a lad aged 15, an under gardener, who came under observation on October 6th. The drains of the house in which he resided are said to have been defective. His sister had died of "pneumonia" in the same house some time previously, and her death is now considered to have been due to enteric fever.

Enteric fever in the *Branston Rural District.*—This district had, at the census 1901, an area of 71,944 acres, and a population of 12,906 persons. Cases of enteric fever have been notified in it during each of the years 1895 to 1903, for the most part in localities distant from Lincoln. A case which, however, was probably an imported one, occurred in Boultham in 1902. In this rural district, a mile or so south-east of the City, is situated the *Bracebridge Lunatic Asylum*, which has an average number of about 880 residents. It was the seat of a severe outbreak of enteric fever, attributed to defective drainage in 1888, when some 108 cases occurred.

The following table (Table IV.) gives the number of notifications of and deaths from enteric fever in the Branston Rural District during the period 1895–1903.

TABLE IV.—Showing for the Branston Rural District (Population 12,906) during the period 1895–1903 inclusive, the notifications of and deaths from enteric fever.

Year.	Number of Notifications.	Number of Deaths.
1895	5	2
1896	6	1
1897	7	3
1898	16	3
1899	4	—
1900	12	3
1901	6	2
1902	3	—
1903	3	—

During 1904 and prior to the epidemic in Lincoln three cases of enteric fever were notified in the Branston Rural District. Two of them, a brother and sister, aged respectively 18 and 14, were notified on April 25th. They lived at Nocton Fen, some miles below Lincoln, on the banks of the Witham. The third case, a boy aged 18, was notified on September 26th, at Navenby, a village some miles from Lincoln, the fever, it is stated, having been imported

from London. At the Bracebridge Lunatic Asylum, a patient, M. J. B., is entered on the weekly list of sick persons on 29th September as suffering from typhoid fever; her name appears on the weekly list on 20th October, but it is not on that for 27th October. This case was not notified to the Medical Officer of Health.

The Rise and Progress in Lincoln and its neighbourhood of the Enteric Fever Outbreak of 1904–5.

Notifications of enteric fever in 1904.—During the year 1904, six cases of enteric fever were notified in the City of Lincoln up to the beginning of the month of December, as follows :—

	Date.	Sex.	Age.	Residence.	Remarks.
1.	6 January, 1904	F.	25	241, Smiths Road	Died
2.	22 March „	M.	10	19, Coningsby Street	Died*
3.	23 August „	M.	25	33, Stamp End	Died
4.	5 September „	M.	40	12, Chestnut Street	—
5.	16 „ „	F.	33	34, Turner Street	—
6.	15 October „	M.	18	67, Chaplin Street	Died

* In the death certificate of this case the cause of death was stated to be "tubercular meningitis."

Onset of the epidemic.—On 2nd December, 1904, H. H., aged 19, was notified as suffering from enteric fever at 14, Bellevue Gardens, a small house standing on high ground in the west-central part of the City; it is occupied by a large family and has only two bedrooms. The water closet is outside the house; no sanitary defect was discovered. The patient, a young man in delicate health, had not been away from Lincoln for seven weeks. No shell fish had been eaten by him.

No further case occurred until 22nd December, when one was notified from 14, Minster Yard. No second case took place in this house, which is a large one, near the cathedral. The patient—E. W., aged 35—had worked during the day in an office in the city. Later a clerk in this office was attacked, and some cases occurred among the employés of a bank adjoining the office. The house drains of the office and the bank premises were found to be defective.

Two further cases were notified on 27th, and two more on the 28th of December, in different quarters of the city. After this additional cases were notified in rapid succession, until on January 23rd, 1905, the number thus brought to the knowledge of the Medical Officer of Health since early December amounted to 29. On January 24th the daily number rose to 13, followed by 23 on January 25th; the number notified in the week 22nd-28th January amounting to 124. Also during this week two cases were notified in the Bracebridge Urban District, and one case in New Boultham.

The following table, Table V., sets out the notifications of enteric fever in the three districts from November 1904 to May 1905.

TABLE V.—Showing the number of cases of enteric fever notified week by week in the City of Lincoln, in the Bracebridge Urban District and in the Branston Rural District from 27th November, 1904, to 6th May, 1905.

Weekly Periods.	City of Lincoln (Population 1901, 48,784).	Bracebridge Urban (Population 1901, 1,752).	Branston Rural (Population 1901, 12,906).
1904.—27 Nov.– 3 Dec. ...	1	—	—
4 Dec.–10 „ ...	—	—	—
11 „ –17 „ ...	—	—	—
18 „ –24 „ ...	1	—	—
25 „ –31 „ ...	9	—	—
1905.— 1 Jan. – 7 Jan. ...	7	—	—
8 „ –14 „ ...	3	—	—
15 „ –21 „ ...	4	—	—
22 „ –28 „ ...	124	2	1 (1 in New Boultham).
29 „ – 4 Feb. ...	265	5	10 (6 in New Boultham).
5 Feb.–11 „ ...	155	7	5 (5 in New Boultham).
12 „ –18 „ ...	103	1	5 (3 in New Boultham).
19 „ –25 „ ...	59	1	1 (1 in New Boultham).
26 „ – 4 Mar. ...	35	1	—
5 „ –11 „ ...	55	2	2 (2 in New Boultham).
12 „ –18 „ ...	38	1	1
19 „ –25 „ ...	32	3	1 (1 in New Boultham).
26 „ – 1 April ...	38	1	4 (4 in New Boultham).
2 Apl. – 8 „ ...	29	1	1
9 „ –15 „ ...	20	2	—
16 „ –22 „ ...	17	—	—
23 „ –29 „ ...	6	—	—
30 „ – 6 May ...	5	—	—
	1,006†	27	31*

* Of the 31 cases notified in the Branston Rural District, 23 were in the special area of New Boultham.
† Exclusive of two cases each of which was reported at a late period and after death.

It appears from this table that 24 cases of enteric fever had been notified in the City of Lincoln during the five weeks immediately preceding the sudden and striking increase of the disease in the week 22nd to 28th January, 1905; and that the week in which the greatest number of notifications was received was that ending 4th February. Further, it is to be noted that the acme of the outbreak having been attained, the number of attacks quickly fell off, though cases continued to be notified until and into the month of May. Not the least conspicuous fact in the table is the circumstance that, coincidently with the sudden increase of enteric fever in Lincoln, above referred to, came considerable prevalence of the disease in the adjoining district of Bracebridge and in the special area of New Boultham in the Branston Rural District; 27 cases (with three deaths) being notified in the former district, and 23 (with three deaths) in the latter during the epidemic period.

The following table (Table VI.) indicates the proportions in which during the epidemic the inhabitants of Lincoln, Bracebridge Urban and of New Boultham respectively, were attacked by and died of enteric fever.

TABLE VI.—Showing for the City of Lincoln, the Urban District of Bracebridge, and New Boultham, a part of the Boultham Parish of the Branston Rural District, the estimated population, the number of attacks by and deaths from enteric fever from 27th November, 1904, to 6th May, 1905; together with the attack rates and death-rates from enteric fever per 1,000 inhabitants, in each instance.

District.	Estimated Population.	Number of Attacks by Enteric Fever.	Attack rate per 1,000 of Population.	Number of Deaths from Enteric Fever.	Death-rate per 1,000 of Population.
City of Lincoln	51,419	1,008	19·6	119	2·31
Bracebridge Urban District ...	1,900	27	14·2	3	1·58
New Boultham, part of Boultham Parish, Branston Rural District...	885	23	26·0	3	3·28
Total	54,204	1,058	19·5	125	2·31

These figures show that the relative incidence of the fever in Bracebridge was lower in respect both of attacks and deaths than in either Lincoln or in New Boultham; and that the attack rate and death rate for New Boultham was higher than that of Lincoln. The Bracebridge and New Boultham rates, however, are calculated on populations which are numerically small; they cannot, therefore, properly be regarded as affording a secure basis for comparison.

The following table (Table VII.) shows the incidence of the fever on each of the several wards of the City of Lincoln:—

TABLE VII.—Showing for each of the six wards of the City of Lincoln the number of houses in each ward with the percentage of these to the total number of houses in the City, the number of notifications of enteric fever in each ward, and the percentage of these to the total number of notifications, together with the number of notifications in excess of one per house, and the total number of houses invaded, the percentage of the houses invaded to the total number of houses in each ward, and the proportion of houses to each invaded house.

Wards.	Number of houses.	Percentage of total number of houses in the City.	Number of notifications.	Percentage of total number of notifications.	Number of notifications over one in each house.	Total number of houses invaded.	Percentage of houses invaded to total houses invaded.	One house invaded in the following number of houses.	Percentage of houses invaded to the total number of houses in the ward.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Minster	1,964	15·99	117	11·63	17	91	11·11	1 in 21·58	4·63
Carholme	2,102	17·12	137	13·62	26	116	14·17	1 „ 18·12	5 52
Castle	1,845	15·03	155	15·40	44	122	14·90	1 „ 15·12	6·61
Abbey	2,273	18·52	168	16·70	45	144	17 58	1 „ 15·78	6·34
Witham	1,941	15·81	189	18·79	73	145	17·70	1 „ 13·39	7·47
Park	2,152	17·53	240	23·86	68	201	24·54	1 „ 10·25	9·34
	12,277	100·00	1,006	100·00	273	819	100·00		

It appears from this table that there was irregularity of incidence of the fever in the several wards of the City of Lincoln ; those most severely affected having been the Park and Witham wards, while the Minster and Carholme wards suffered least.

The succeeding table (Table VIII.) shows for the City of Lincoln (similar facts are not obtainable for Bracebridge Urban District and New Boultham) the incidence of the fever in relation with age and sex, as regards both attacks and deaths, and also the corresponding attack and death-rates per 1,000 persons living of each age group.

TABLE VIII.—Showing for the City of Lincoln the number of attacks by and deaths from enteric fever at all ages, and in several age groups, and the corresponding attack and death-rate in both sexes from 27th November, 1904, to 6th May, 1905.

Age Groups.	Estimated Population	Number of Males.	Number of Females.	Number of Attacks.		Attack rate per 1,000 living.		Number of Deaths.		Death-rate per 1,000.	
				Males.	Females	Males.	Females	Males.	Females	Males.	Females
0—5	5,242	2,566	2,676	50	34	*19·5*	*12·7*	1	1	*0·39*	*0·37*
5—10	5,018	2,477	2,541	99	55	*40·0*	*21·6*	4	1	*1·61*	*0·39*
10—15	4,858	2,405	2,453	84	77	*34·9*	*31·4*	9	4	*3·74*	*1·63*
15—25	10,617	5,148	5,469	159	122	*30·0*	*22·3*	18	14	*3·50*	*2·56*
25—35	8,545	4,113	4,432	91	78	*22·1*	*17·6*	12	14	*2·92*	*3·16*
35—45	6,408	3,079	3,329	48	43	*15·5*	*12·9*	10	7	*3·25*	*2·10*
45 upwards	10,731	5,174	5,557	38	30	*7·3*	*5·4*	17	7	*3·29*	*1·26*
Total all ages	51,419	24,962	26,457	569	439	*22·8*	*16·6*	71	48	*2·84*	*1·81*

This table shows that at all ages, and for each age group, males suffered a greater incidence of attack than did females, and that the fatal incidence on males was likewise greater than on females, except in the age group 25–35 years.

It appears also that there was special incidence of attack on children and young adults, those in the age group 10–15 years being the greatest sufferers. The death-rate, however, was highest among persons between the ages of 15–35 years.

In the next table is set out the case mortality of the enteric fever in the various age groups.

TABLE IX.—Showing for the City of Lincoln between 27th November, 1904, and 6th May, 1905, the number of persons attacked by and the deaths from enteric fever, at certain age groups, and the case mortality, at each of these age period.

Age Groups.	Number of Persons Attacked.	Number of Deaths.	Number of Deaths per cent. of Attack.
Under 5 years	84	2	2·38
5—10	154	5	3·25
10—15	161	13	8·07
15—25	281	32	11·35
25—35	169	26	15·38
35—45	91	17	18·68
45 and upwards.	68	24	35·29
Total	1,008	119	11·81

This table shows that with increasing age the liability to a fatal termination to the illness became progressively greater.

The following table (Table X.) shows the number of houses in the City of Lincoln invaded by enteric fever ; and the number of houses in which more than one case of the fever occurred, with the house-invasion rate.

TABLE X.—Showing for the City of Lincoln the number of houses invaded by enteric fever between 27th November, 1904, and 6th May, 1905, and the number of houses in which more than one case of the fever occurred ; together with the rate of invasion on the houses in the whole of the City, and the percentage in each instance of the invaded houses having one and having more than one case of the fever.

Estimated number of houses.	Total number of houses invaded.	Percentage of house invasion.	Number of houses with but a single case.	Number of houses with two cases.	Number of houses with three cases.	Number of houses with four cases.	Number of houses with five cases.	Number of houses with six cases.	Percentage of invaded houses having—	
									One case.	More than one case.
12,277	819	*6·3*	706	79	27*	2	4	1	*86·2*	*13·8*

* One of these cases was notified after 6th May, 1905.

The cases occurring in Public Institutions are not included in the above figures.

These figures show that in all 6·3 per cent. of the private dwelling houses in the City suffered invasion by enteric fever, and that of the houses invaded as many as 86 per cent. had not more than a single case of fever.

Of the cases that occurred in private houses about 38·1 per cent. were removed to hospital ; these cases were removed from 33·0 per cent. of the invaded houses. In houses where more than one case occurred the first case notified was removed in 35·7 per cent.

Doubtful cases of Fever. Type of Fever. Prevalent Influenza.—In a very large percentage of the enteric fever cases notified, the diagnosis was confirmed by Widal's reaction. In one type of case, of which there were a good many, though all the initial signs and symptoms of enteric fever had been present, the patient appeared to be convalescing favourably towards the tenth day of his attack ; nevertheless, in the third week hæmorrhage from the bowel occurred. Bleeding from the intestines was, indeed, fairly common among the patients, and many severe cases occurred.

At the time of the outbreak of enteric fever, an epidemic of influenza prevailed in the City, with the result that in many cases there was difficulty in distinguishing between the two diseases. But of the patients taken into hospitals the course of the disease showed that very few mistakes had been made in diagnosis. In March and April, 1905, several notifications of enteric fever were received of patients who for some weeks previously had been under treatment for influenza, and who appeared to have developed enteric fever whilst convalescing from influenza.

The epidemic of enteric fever broke out during the Christmas school holidays, hence it happened that children returning from Lincoln to boarding schools in different parts of the country developed the disease after their return to school. Also in several instances persons from Lincoln fell sick of the fever in London and other places. Enteric fever was also introduced into the Welton Rural District, which adjoins Lincoln, by servants sent to their homes when they fell ill in Lincoln and before the nature of their ailment was known ; there was no spread of the disease in this district.

Sanitary Condition of the City of Lincoln, Bracebridge Urban, and New Boultham.

City of Lincoln.—The sanitary administration of the City is carried on by the City Council acting as a Sanitary Authority. This work is apportioned to Committees, of which those prominently concerned, administratively, with this outbreak of enteric fever were the Health Committee, the Water Committee, and a Special Committee formed during the epidemic, with the Mayor as Chairman, to deal with the question of the water supply to the town.

There are no "slums," in the ordinary acceptance of the term, in Lincoln. From time to time the clauses of the "Housing of the Working Classes Act" have been put in force, and insanitary houses closed, until they have been placed in a sanitary condition. "Down hill," for the most part the houses are of comparatively recent erection; there are whole streets of small houses newly built, to accommodate the artizan class. Though some of the houses of the poorer classes, especially those on the banks of the river, are old and often dilapidated, and their interiors dirty, such houses are the exception and not the rule. The town has a distinctly clean appearance, the streets are well scavenged and the houses well kept. The number of houses built appears to keep pace with the demand for dwellings, and overcrowding of persons in houses exists to a small extent only.

Pigs are kept in considerable number, and often in insanitary surroundings in the City; and with the growth of the City certain small farmhouses, with their improperly drained farmyards and cowsheds, have become surrounded by extension of the building operations. Some of these cowsheds are defective in drainage, ventilation, and cleanliness, and there are slaughter houses and common lodging houses in need of attention at the hands of the Sanitary Authority. There is, however, an excellent public abattoir, and two of the common lodging houses are far superior, and one especially so, to many to be found in large towns.

Bracebridge Urban District.—The houses in this district have been built at different periods. There are houses which are old, damp, and somewhat dilapidated, short streets of comparatively modern houses, and similar streets of houses quite recently erected. It really is a district in which there are old houses which have become, as it were, absorbed by extension of building in comparatively recent years, and it constitutes rather less a suburb than a portion of the City of Lincoln. Taken as a whole the sanitary condition of the district, though it cannot be described as bad, nevertheless leaves the impression that it compares somewhat unfavourably with Lincoln, principally on account of the existence of nuisances in greater proportion.

New Boultham, on the other hand, contains few if any old houses. It is largely occupied by certain manufactories; and the artizans and workmen employed in these factories live in comparatively modern dwellings in the vicinity of the works. Such nuisances as exist are mainly due to the erection in the rear of out-houses for live stock and to other unwholesome conditions familiar in districts inhabited by the working classes.

Brief description of the Water Supply, Sewerage, House Drainage and Disposal of Excrement in the area invaded by Enteric Fever.

Water Supply.—The Corporation of Lincoln are the proprietors of the waterworks.

The water supply is derived partly from the land drains which receive surface water from a large tract of agricultural country, partly from water which collects in old extensive excavations for sand, and partly from water taken from the River Witham above the point where this stream reaches the City.

The water is subjected to filtration through sand before being sent to the consumers. It is pumped through rising mains, which serve also as distributing

mains, to two reservoirs situated on high ground on opposite sides of the City ; from the reservoirs, which between them hold roughly one day's supply, the water gravitates to the town and district when pumping ceases, or when the demand for water exceeds the quantity pumped from the waterworks.

The Lincoln water mains extend into the Bracebridge Urban District, and into New Boultham, and, with the exception of a few scattered houses on the outskirts which obtain their water from local wells, the water from the Lincoln Corporation Waterworks constitutes the supply of these places. It is also supplied to the Bracebridge Lunatic Asylum and to twenty-five private residences in the Branston Rural District outside the area of New Boultham.

A full account of the water supply is given in Appendix I.*

The Sewerage System.—The City of Lincoln is sewered practically throughout its inhabited area. The branch sewers join up to two main sewers, which in turn are connected with a large tank, from which the sewage is raised by pumping to the sewage farm on the outskirts of the City. After treatment at the sewage farm, the sewage effluent is discharged into the Sincil Dyke, which opens to the River Witham some miles below the City. To this sewerage system are connected the sewers of the Bracebridge Urban District and of New Boultham. All the houses in New Boultham and 90 per cent. of those in Bracebridge are drained to sewers that connect with those of Lincoln. The sewers in the two last-mentioned areas, as well as in Lincoln, are for the most part ventilated by road gratings, but in the central part of the City ventilating shafts have been substituted. Certain sewers are flushed automatically, others are flushed with water from carts. In certain parts the rain water and road washings are dealt with by a separate system of sewers, which discharge into the River Witham.

House Drainage, Disposal of Excrement and Refuse.—In Lincoln, Bracebridge, and New Boultham, houses generally drain to glazed earthenware socketed pipes; ventilation of house drains and disconnection of houses from sewers are commonly satisfactory, save that where outdoor waterclosets exist, disconnection from the sewer is, as a rule, dependent on one trap. Lincoln is mainly a watercloset town, and most of the waterclosets are situated outside the houses. In Bracebridge, on the other hand, some two-thirds of the houses are served by vault privies, while in New Boultham about 60 per cent. have waterclosets.

A detailed description of the sewerage, house drainage, and methods of disposal and removal of excrement and refuse is given in Appendix II.

Causation of the Fever.

In endeavouring to account for the origin and spread of the fever which, in epidemic form, invaded the City of Lincoln, the Bracebridge Urban District, and New Boultham, in the circumstances that have been described, no agency can be regarded as affording a satisfactory explanation unless it be common to the three invaded areas, and of a sort capable of disseminating the malady in a fashion not inconsistent with the facts observed.

Regarded from this point of view, unwholesome conditions of individual dwellings and their surroundings may be dismissed from consideration, as not conceivably serving to account for more than a fractional portion of the epidemic. So also with particular methods of excrement disposal, regarding which, however, there is, it may be noted, material difference in the three areas involved.

There remain for consideration, among the agencies commonly regarded as apt to be associated, in causative fashion, with prevalence of enteric fever, milk, sewerage and drainage, and water supply.

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* This water supply has not in the past been considered satisfactory, and the circumstances associated with it have from time to time been brought to the notice of the City Council by the Local Government Board. *See* especially pp. 27 and 28.

Milk.

In this instance, the investigations made with a view to ascertaining whether milk had been the vehicle of transmission of the fever, lent no support to such a thesis. It was found that the first 48 cases of the disease derived their milk-supply from no fewer than 32 different sources ; and, throughout the whole course of the epidemic, the facts ascertained in relation with this question failed to suggest that milk played a part as a distributor of the infection, whether in Lincoln, Bracebridge, or New Boultham.

Sewerage and Drainage.

As has been stated, one system of sewers serves Lincoln, New Boultham, and the great majority of houses in the Bracebridge Urban District ; and the conditions of house drainage are much the same in each. Here then there is an agency, common to the three invaded areas, which is presumed to be a possible means of distributing the infection of enteric fever. But if the fever had in this instance spread by such channel, there would, it may reasonably be contended, have occurred very special incidence of the disease on houses to the interiors of which sewer-air could, by reason of defective sanitary fittings, gain access. In each of the first 25 houses invaded, however, the interior was efficiently disconnected* from the house drains, nor, moreover, could sewer-air have gained access to the interior of 21 of these houses by means of defective soil pipes, inasmuch as they were not provided with indoor waterclosets. Indeed, out of a total of 834 invaded houses, in regard of which information of this sort is available, only 73 had indoor waterclosets. Again, had sewers played an important part in causation of the epidemic, it is to be anticipated that there would have occurred special incidence of the fever in relation with a particular sewer or line of sewers, more especially in the early stages of the outbreak. But, as matter of fact, no such special incidence was observed. The first 25 cases occurred at spots widely apart and in every quarter of the City of Lincoln ; while the subsequent progress of the epidemic was characterised by like behaviour throughout all the three areas involved. Nor was any special incidence of the fever noted in relation with dead-ends of sewers ; nor on the higher parts of the invaded areas, which are maintained by some to be particularly liable to invasion by disease transmitted by sewers. There was, indeed, greater incidence of the fever on the low-lying Park and Witham wards of the City of Lincoln than on other wards of the City, as will be seen on reference to Table VII. (p. 9). For, whereas the percentage of houses invaded by the fever in Lincoln as a whole was 6·3, the percentage of such invasion was 9·34 in the Park ward and 7·47 in the Witham ward ; while the percentage invasions in the Minster and Carholme wards were but 4·63 and 5·52 respectively. It is in these low-lying wards that difficulty was experienced, by reason of the nature of the ground, in laying satisfactory sewers when the present sewerage system of Lincoln was installed (*see* Appendix II., p. 33) ; and it may be contended that the sewerage conditions in these wards stood in some degree of causative relation with the greater amount of fever experienced there than in other parts of the City. On the other hand, it is to be borne in mind that these two wards are inhabited mainly by the working-class, which usually comprises a disproportionate number of persons at ages most susceptible to enteric fever, and which lives under the conditions rendering the individual more prone to contract enteric fever than is the case with the well-to-do class.

As appears in Table V. (p. 8), eight of the 31 cases of fever known to have occurred in the Branston Rural District did not reside in New Boultham, and accordingly did not occupy houses draining to the sewerage system common to the three invaded areas. Two† of these cases occurred in the Bracebridge Lunatic Asylum. With one exception, all these eight persons had been frequent

* The house drainage of the office where "E.W.," the second notified case, worked daily were, however, defective. *See* p. 7.

† One of these cases is certified as having died from acute phthisis. The circumstances, however, seem to point to this person having suffered from enteric fever also.

visitors to Lincoln. It is, however, questionable whether this fact may properly be held to account for their having contracted the fever, if sewers are to be regarded as the agency whereby transmission of the disease was effected.

As result of inquiry into the incidence of the fever on the five chief public institutions within the City of Lincoln, in relation with the thesis of sewer-infection, it appeared that three of these were invaded by the fever, while two escaped. One of those (the Prison) that escaped does not drain to the Lincoln sewer; the other, as well as the three invaded, does. Those invaded suffered proportionally much less than did Lincoln as a whole, with the exception of the workhouse, to which reference will be made later. But, in view of the small number of persons concerned in each instance,* and of the small proportion of them who were of ages at which enteric fever is of most frequent occurrence, no conclusion as to question of relationship at these institutions between the fever and sewerage conditions could properly be arrived at.

The several facts and considerations set forth, while not inconsistent with sewerage conditions having played some part in the propagation of enteric fever in the invaded areas, do not support the view that in them is to be found the source of the epidemic, and that to them may be referred the greater or even a large share of the fever witnessed; and, indeed, the very manner of inception of the outbreak would seem to negative such an hypothesis. For its acceptance it is necessary to postulate practically simultaneous contamination of widely remote points of an extensive system of sewers with infective material as to the origin and manner of conveyance of which it is not possible to form any reasonable conception.

Water Supply.

On the other hand the behaviour of the outbreak is consistent with a theory of water-borne infection. The occurrence of a few cases of enteric fever, widely distributed, and followed at no long interval by sharp and sudden increase of attacks, rapidly culminating in an outburst of explosive intensity, are features that have been frequently noted in association with epidemic prevalence of this disease when caused by specific pollution of a public water supply. As may be seen on reference to Table V. (p. 8), and to the map and charts that accompany this report, it was in this fashion that the fever manifested itself in this instance. Thus: following upon a case notified on the 2nd December and another notified on the 22nd December, there occurred in the course of four weeks 23 additional cases scattered widely over Lincoln: then, in the course of a single week, that ending January 28th, ensued great and sudden increase of the fever, no less than 124 cases being notified; while, in the week ending the 4th February, which formed the culminating point of the epidemic, the number of cases notified attained to 265.

As has been already stated, Lincoln, Bracebridge, and New Boultham derive practically the whole of their water from the public supply of the Corporation of Lincoln. This water is also furnished to the Bracebridge Lunatic Asylum,† which is in a part of the Branston Rural District on the side of Lincoln opposite to that occupied by New Boultham, and to twenty-five private residences in that district, but not in New Boultham. Two of these private residences were invaded by the fever, as also was the Asylum. In this Asylum, which has a population of 880, only two cases are known to have occurred, the first of these being the one already referred to as certified to have died of acute phthisis. This case was notified on the 16th February and died on 23rd April. The other case was notified on 7th April, and, for a reason which will presently appear, is not likely to have contracted the fever through drinking the public water supply. She may, however, have been infected by the first case, whom she nursed. The known incidence of the fever on the Asylum was, therefore, slight. It is to be borne in mind, however, that the proportion of persons in the Asylum at ages at which enteric fever is most liable to occur is well below the average, and also

* None of these institutions has a population amounting to as much as 300.
† This institution is not on the Lincoln Sewerage System.

that the water consumed in this institution is stated to have been boiled before use at an early stage of the outbreak, viz., on and after the 23rd January. In addition to the foregoing, four other cases of fever are known to have occurred in the Branston Rural District outside New Boultham. None of these persons resided in houses furnished with the Lincoln water, but three of them were frequent visitors to Lincoln, and are known to have drunk unboiled water there. The fourth is stated to have drunk tea only when in Lincoln.

It appears, therefore, that not only was the fever prevalent throughout the three populous areas almost wholly served by this public water supply, but also that it was associated with the distribution of this supply outside these areas, although, it is true, in but small amount in a sparse population. This fact, and the manner of inception and progress of the outbreak, already described, afford ground for presumption that the public water supply of the Corporation of Lincoln was concerned in the dissemination of the fever. Question arises, accordingly, whether the circumstances of this supply were such as would suggest its liability either to direct infection with the specific contagium of enteric fever or to pollution of a sort commonly associated with such specific infection. In Appendix I. to this Report a detailed description of the sources of the Lincoln supply is given ; and it appears from this account that at several points washings from manured ground, farmyard drainage, domestic sewage, and other polluting matters can gain access to the supply. It appears, also, that heavy rains are likely to lead to increased danger of pollution of the supply in the above ways, and that, as matter of fact, such rains occurred in December, 1904, and January, 1905. Study of the data given on pages 22 and 23 of Appendix I. indicates relationship between rainfall in these months and subsequent occurrences of fever in the invaded areas. Moreover, it would seem that the amount of "purification" of the water likely to be afforded by the inadequate and irregular filtering arrangements shown to have existed at the waterworks was probably still further diminished by occurrences of frost during the two months in question.

It is, indeed, rendered abundantly clear by the particulars given in Appendix I., that this public water supply has been liable to pollution of a sort involving serious danger of its contamination with the infective material of enteric fever. Thus, heavy rains could greatly increase the amount of this pollution and its accompanying danger, while at the same time diminishing such protection to the consumer of the water as may be looked for from the filters at the waterworks. And further it is seen that such rains did, in fact, occur immediately antecedent to the outburst of the fever.

Search was made for the bacillus typhosus, the specific micro-organism of enteric fever, in the water of the public supply ; and, from a sample taken from one of the sources of this supply on February 1st, a micro-organism was recovered which resembled the bacillus typhosus in all essential respects. A similar micro-organism, which was regarded as possibly being the bacillus typhosus somewhat altered in character by sojourn in the water, was isolated from a sample of sediment taken from the "pure-water tank," which receives the water after filtration, at the waterworks on February 11th.

Review of the foregoing facts and considerations may reasonably be held to justify inference that the fever which affected the City of Lincoln, the Bracebridge Urban District, and New Boultham, owed its origin to specific pollution of the public water supply shared in common by these places ; and that this supply was the medium whereby the infection was transmitted in the large majority of the cases during the epidemic which ensued. But, however strongly the evidence available may support this thesis, it cannot be regarded as excluding the view that a proportion of the cases is not to be accounted for in this way. For reference to page 26 of Appendix I. shows that chemical treatment of the public water supply, with a view to destruction of infective material it might contain, was commenced on the 11th February, and had so far progressed in days following as to afford ground for presumption that this water was no longer a vehicle of infection by the 22nd February. If due allowance be made for incubation and notification of the fever, it would follow, on this presumption, that cases notified after the 15th March would not be referable to infection conveyed by the public water supply. From the 16th March to the

6th May, however, 177 cases of enteric fever are known to have occurred. Of these, 156 occurred in private houses, and 21 in public institutions. As regards the 156 resident in private houses, there had, in 74 instances, either been an antecedent case of the disease in the house or the person attacked had been exposed to infection by nursing the sick. As regards the remaining 82 explanation of this sort was not forthcoming, and the source of their infection could not definitely be traced. They were distributed throughout the invaded areas, and in few instances only were the houses in which they resided discovered to be in defective sanitary condition. A similar persistence of enteric fever, after an implicated water had ceased to be considered operative in causing enteric fever, was observed in the Maidstone epidemic of 1897. In Maidstone, this continuance of fever was referred in part to direct infection from previous cases, in part to infection of the soil by the micro-organism of enteric fever conveyed thither through leaky drains and sewers or in other fashion easy of comprehension. Like explanation may be entertained of the persistence of the fever in this instance.*

Of the 21 cases of enteric fever in public institutions after the 15th March, 18 occurred in the workhouse, which has a population of some 280 persons. These cases were notified between the dates of 1st April and 6th May, and seem to have been referable either to direct infection from person to person, or to the consumption of water from a well within the workhouse grounds. This well was resorted to on the 18th February, the date on which the use of the public water supply was ordered to be discontinued. The circumstances of the workhouse well were such as to render its water liable to risk of dangerous pollution; it is not, however, clear in what way specific contamination of the water can have occurred.

Before closing this Report, I welcome the opportunity of expressing my appreciation of, and my thanks for, the unvarying courtesy and assistance which I experienced from the members of the Corporation of Lincoln, their officers, and from many private persons. Nor can I omit a reference to the excellence of the work done in Lincoln during the epidemic. Whatever may have been the sins of commission or omission of their predecessors, the Corporation, ably supported by their officers and by the citizens, in the hour of trial did their duty and dealt with the varying circumstances of the epidemic in a resolute, prompt, and efficient manner.

RICHARD J. REECE.

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* In this connexion it deserves to be borne in mind that in all extensive outbreaks of enteric fever there is ground for suspicion that a not inconsiderable number of cases escape notification, as in the case of persons suffering from mild attack and experiencing only a feeling of malaise. Such person, going altogether untreated, and possessing as he does the power of communicating the disease in its severer forms to healthy people, is in a sense more dangerous to his fellows than the subject of a severe attack, which being recognised brings about isolation of the patient, along with measures for limiting the dissemination of virus multiplied within his body.

Such mild cases of enteric fever, accompanied with but minor symptoms of illness would, during the enteric fever epidemic in Lincoln, have been peculiarly liable to have been overlooked owing to the prevalence of influenza in that city.

APPENDIX 1.

LINCOLN WATER SUPPLY.*

History of the Water Supply.—Prior to 1847 the water supply of Lincoln was for the most part derived from wells, though doubtless persons living on the banks of the River Witham and the Sincil Dyke supplemented their supply from these sources.

In the year 1846 a company obtained power, by the Lincoln Waterworks Act, 1846, to supply the City of Lincoln and its immediate neighbourhood with water; and in the year 1847 the Waterworks were commenced, and completed in 1848, at a cost of £24,000. These works, which were among the first of their kind erected in England, consisted of one impounding reservoir, one service reservoir, and two filter beds. The Waterworks were provided with pumping power equal to 33 horse-power.

The impounding reservoir, the Hartsholme Lake at Skellingthorpe, some two miles from Lincoln, of irregular shape and depth, has an area of 23 acres and an estimated storage capacity of 20,000,000 gallons. It was constructed by excavating in a natural depression or small valley and building an embankment. The service reservoir at Westgate in the City, close to the cathedral, is an uncovered reservoir having an average length of 162 feet, width 96 feet, depth 8 feet, area 15,552 square feet, and a cubic capacity of 124,416 feet, the storage capacity being estimated at about 777,000 gallons. The pumping engine and the two filter beds were placed at Boultham, on the bank of the River Witham opposite Lincoln, at a point where the Catchwater Drain opens into, and the Sincil Dyke leaves, this stream. The filter beds received water from the Hartsholme Reservoir by gravitation. Each bed was 62 feet long and 41·5 feet wide, the area being for each bed 286 square yards, or a total of 572 square yards. The source of the water flowing into the Hartsholme Reservoir is stated to be from sand and gravel underlying moorland.

This supply to the City, which was a constant service, commenced on 26th March, 1848, at a time when the population was estimated at 17,000 persons. It was calculated that 25,000 inhabitants could be daily supplied with 20 gallons of water per head.

Under the Lincoln Waterworks Act, 1871, the Corporation purchased the Waterworks.

With the increase of the population (shown in Table II.) additional works were required. In 1875 a second service reservoir was constructed on the Cross Cliff Hill in the Branston Rural District. This is an uncovered reservoir having a mean length of 220 feet, width 120 feet, depth 10 feet, an area of 26,400 square feet, and capacity of 264,000 cubic feet, and estimated storage capacity of 1,650,000 gallons.

In March, 1882, two impounding reservoirs were added. These are situated on the west and east side of the Midland Railway line at Boultham, about one mile south-west from the pumping station, and are excavations from which sand has been dug. They are known as the Midland and Boultham Ballast Pits or Holes. The water from these ballast holes passes by gravitation direct to the filter beds at the pumping station. The Midland Ballast Pit has an average length of 616 yards, width 88 yards, depth 6 feet, area 11¼ acres, and an estimated storage capacity of 16,000,000 gallons. The Boultham Ballast Pit has an average length of 242 yards, width 110 yards, depth 7 feet, area 5½ acres, and an estimated storage capacity of 9,000,000 gallons.

Prior to 1885 the pumping power was 1,080,000 gallons per day; in that year another engine was added, capable of pumping 1,300,000 gallons per day, as the old engine made in 1836, pumping 460,000 gallons a day, could not be relied on for regular work.

In 1866 a filter bed, having an area of 330 square yards, was added, and in 1878 the two original filter beds were enlarged by adding to each a length of 64 feet, and width of 51 feet, the area of each being 724 square yards, making a total filtering area of 1,626 square yards. In 1884 two other filter beds were added. They were 122 feet long by 61·3 feet wide, area of each 830 square yards; but the filter bed of 330 square yards area (constructed in 1866) at this time ceased to be used, so that the filtering area was increased by 1,330 square yards.

At the time Dr. Harrison reported on the water supply in 1885 the impounding and service reservoirs and the filtering area were as follows:—

Impounding Reservoirs.

One at Hartsholme (Skellingthorpe), estimated capacity	...	20,000,000 gals.
One at Boultham, Midland Ballast Pit, „ „	...	16,000,000 „
One at Boultham, Boultham Ballast Pit, „ „	...	9,000,000 „
		45,000,000 gals.

* In 1885 Dr. Harrison made a report to the Corporation of Lincoln respecting the water supply of the City. I am indebted to this report for most of my information concerning the history of the Water Supply of Lincoln.

Service Reservoirs, uncovered.

1. Westgate, 124,416 cubic feet	777,000 gals.
2. Cross Cliff Hill, 264,000 cubic feet	1,650,000 „
	2,427,000 gals.

Filter Beds.

One area	648 square yards.
One area	648 „ „
One area	830 „ „
One area	830 „ „
	2,956 square yards.

To these filter beds two more were added in 1904, each having a filtering area of 720 square yards.

Dr. Harrison reports (1885) that :—

The service is constant and, as a rule, without cisterns. In Lincoln, and in the special drainage district of Bracebridge, about 8,800 houses are supplied, giving about 20 gallons per head per diem to 43,000 people. During December, 1884, 880,584 gallons were supplied daily.

The Lincoln Waterworks Act, 1871, which enabled the Company to sell the Waterworks to the Corporation, also gave power to take water from the Upper Witham River, and from the Pike Drain and Catchwater Drain which flow into the River Witham, and from the Prial Brook which opened into the Hartsholme Reservoir.

Water from all the sources mentioned above contributed to the supply of the City of Lincoln in 1904.

In addition to this water supply from the Corporation Waterworks there is a supply known as the "Conduit" water. This water springs from the limestone in the Mainwaring Estate in the east of the City, and is brought most of the way in iron pipes, but about 500 yards of the old lead pipes are still left in. It is laid on to drinking fountains in the city at Baggeholme Road, Free School Lane, High Bridge, and in the High Street at St. Mary's-le-Wigfords and St. Peter-at-Gowts Churches. There is also another water known as the "Spa" water ; it emerges on the south side of the Great Central Railway. It contains iron, and has been drunk for medicinal purposes.

In the older parts of the City there are a considerable number of surface wells, the water from which was not used, except for flushing purposes, after the public water supply was installed. During the epidemic of 1904-5, however, some of these wells were again taken into use for household purposes.

The Staff of the Waterworks consists of :—

One water engineer, Mr. Teague, Junior.*
One foreman.
Two engine men.
Three boiler men.
Seven filter bed men.

There are also eight turncocks and inspectors, and two clerks in the office of the water engineer at the Corporation offices, and casual labourers are engaged as required.

The foreman, a man aged 73, died of pneumonia a few days before my first visit to Lincoln.

There have only been two water engineers at Lincoln. Mr. Teague, Senior, the first engineer, came to Lincoln to erect the pumping machinery in 1847 ; he was subsequently appointed the water engineer, and he held the appointment until 1898, when his son was elected to the office. The salary is £300 per annum.

Pumping Power.—At the Waterworks are three engines. One is a Worthington triple expansion engine fitted with duplex pumps, and said to be capable of pumping 1,700,000 gallons of water in 24 hours. This is the pump which is generally in use. The second is a rotary engine, which is stated to be able to pump 576,000 gallons in 24 hours ; and the third engine is a single action Cornish (beam) engine, capable of pumping 1,337,307 gallons in 24 hours. This engine is only used when the Worthington engine is being repaired, or when its boilers are being cleaned.

Water Records.—No systematic or written records have been kept at the Lincoln Waterworks as to the number of gallons of water entering the Waterworks from the various sources of supply, nor of the number of gallons of water pumped to the town, nor of the dates on which filter beds have been put out of action for cleansing purposes. The Water-

* Mr. Teague resigned the appointment of water engineer, and towards the beginning of July, 1905, was succeeded by Mr. Neil McKechnie Barron, late water engineer of Margate.

works have no automatic mechanism for recording the amount of water entering the Waterworks, or passing through individual filter beds, nor any means of controlling the rate of filtration except by the closing or opening of sluice valves by workmen.

I found it impossible to obtain, with any approach to accuracy, information on the above points, owing to the absence of any written records.

Mr. Teague, Junior, the water engineer, supplied me with the following data. They are, apparently, based to a certain extent on the number of hours the various engines were at work, and must only be regarded as indicating in some measures the operations at the Waterworks.

In February, 1895, the daily quantity of water pumped was 1,913,307 gallons. Since March, 1900, this rate of pumping was maintained—

One engine lifting	1,337,307 gals.
And another	576,000 „
	1,913,307 gals.

Filtration.—The filtering area was 2,956 square yards when all the filter beds were in use, and 2,126 square yards when one of the beds was out of action for cleansing. When all the filters were at work the rate of filtration was 649 gallons per square yard daily, or $5\frac{3}{4}$ inches per hour. When one bed was being cleaned the rate of filtration was 900 gallons per square yard daily, or 8 inches per hour.

From May to August, 1904, a new filter bed having been added, the filtering area was 3,676 or 2,846 square yards, and the total amount pumped daily being 1,700,000 gallons, the amount filtered per square yard per day was 462 or 600 gallons, at the rate of 4 or $5\frac{1}{2}$ inches per hour.

But at times, owing to dry weather, 2,276,000 gallons were pumped in 24 hours, the number of gallons filtered being 620 or 796 per square yard per day at the rate of $5\frac{1}{2}$ or 7 inches per hour.

On August 20th, 1904, an additional filter bed of 720 square yards area was added, but one of 648 square yards, which had been in use since 1847, was put out of work and its contents entirely cleared out and renewed.

From August 20th to November 19th, 1904, the number of gallons pumped daily was 1,700,000; the number of gallons filtered per square yard 450 or 580; the rate being 4 or 5 inches, according as all the filters were in use or not.

But in order to keep the reservoir at Cross Cliff Hill sufficiently full to supply the Bracebridge Asylum, every Monday the amount pumped was 2,276,000 gallons. Thus on one day a week the number of gallons filtered per square yard was 606 or 777, and the rate $5\frac{1}{2}$ or 7 inches, according as all the filters were used or one was out of action.

After November 19th the filter bed previously put out of work to be renewed was again taken into use, and pumping was carried on at the rate of 2,276,000 gallons during the day and of 1,700,000 during the night. The total amount thus yielded in 24 hours was, therefore, 1,988,000 gallons. During the day, according to whether all the filters were in use or one was out of work for cleansing, the number of gallons filtered per square yard would be 518 or 638, the rate being $4\frac{1}{2}$ to $5\frac{1}{2}$ inches. During the night these figures would be 390 or 476 gallons per square yard, and the rate $3\frac{1}{2}$ or $4\frac{1}{4}$ inches per hour.

I am informed that it is impossible to state when the filter beds were individually in and out of use, or the exact number of gallons of water passing through the filter beds at any given time.

In April, 1905, towards the end of the enteric fever outbreak, an additional filter bed was commenced; it was anticipated that this bed would be completed towards the end of June.

In the absence of subsidence reservoirs, the water passes, on entering the Waterworks, to the filter beds direct; all of which are uncovered and exposed to the inclemency of the weather in winter.

The Waterworks are on the banks of the river, and some years ago the floods completely covered these filter beds.

The filtering material of each filter is 3 feet of fine Trent sand and 1 foot 6 inches of gravel. The depth of water resting on the filter beds is 1 foot 6 inches.

The outflow of the filtered water from the filter beds is controlled by means of valves, which are opened or closed according as the amount passing through is considered to be in excess of what is believed to be the average rate of filtration for a given filter, or as the

demands of the pumping engines have to be satisfied. When the water in the inspection pipe is seen to stand at 12 or 15 inches below the level of the water in a filter bed, that bed is shut off for cleaning. The filter beds are scraped about once a month ; occasionally less frequently than this ; sometimes more frequently, as, for instance, when the water from the Hartsholme Lake or Reservoir is becoming foul with vegetable matters.

The method of cleansing the sand of the filter bed is peculiar. The water is lowered in the filter bed and the surface sand is scraped off to a depth of three-quarters of an inch to an inch, and this dirty sand is dealt with in the sand-washing machine. The sand when cleaned is relaid, not all over the surface of the filter, but over only about an eighth of it, beginning across one end of it to a depth of 6 inches, making, as it were, a step. When the filter is next cleaned the whole surface is scraped and the clean sand again laid down across the filter, beginning from the edge of the raised layer of the sand from the first cleaning, so that the whole surface is covered with a fresh layer of sand in the course of nine months. As the process is continued the depth of the filtering layer of sand at one end of the filter becomes considerably reduced. The Water Engineer could not say why this process was adopted ; it was done in like manner by his father.

After relaying the surface sand, water is run on to the bed and allowed to stand for some time before the bed is used ; this water passes into the supply.

At times when a film, deposited from the filtered water, rapidly covers the filter beds, and filtration becomes more difficult, instead of lowering the water, and cleansing the superficial sand, the surface sand is raked over from the sides to a distance of about ten feet from the edge of the filter bed ; thus removing the obstruction offered to the passage of water over the surface thus broken. The central part of the filter bed, about one-half of the whole area, remains with the deposited scum untouched, and consequently the rate of filtration becomes unequal, the sides permitting water to pass, and the central part allowing little water to filter through. Practically what happens is that the quantity of water filtered is passed through about one-half of the whole area of the bed, which, as shown above, is liable to be unduly thinned at one end of the filter bed. A procedure of this sort invites a breakdown in effective filtration.

I am informed by the Water Engineer that during prevalence of frost, hot water from the condensers of the engines is run on to filter beds that have been cleaned, before they are taken into use, to prevent the sand freezing ; and that when the water standing on the filter beds becomes frozen, it is broken round the edges by the men employed at the Waterworks.

Sand Washing.—The dirty layer of sand scraped from the surface of the filter beds is washed mechanically in an apparatus, consisting of a series of inverted cones or hoppers, into which the dirty sand with hot water from condensers in the boiler is sucked by siphon action, and driven under pressure and violently agitated. This apparatus is said to be capable of washing 120 cubic feet of sand per hour. The result on the sand of this washing, as shown by a bacterial examination of the washed sand made by Dr. Houston, is extremely good. The water used in the sand washing is discharged into the River Witham between the outfalls of the Catchwater and Pike Drains, and as could be seen after some new sand of light colour had been washed, this dirty water is sucked back in part to the Waterworks with the incoming water.

I am informed that the original land owner objected to the water used in sand washing being discharged into the Delph.

Pure Water Tank.—When the water has passed through the filter beds it is received into a pure water tank capable of holding some 4,000 gallons. The water from all the filter beds discharges to and mixes in this tank whence it is pumped into the rising mains. The foreman or engine driver has to maintain about three feet of water in this tank, and he ascertains the depth by dipping in a staff, there being no automatic register for this purpose. If the water falls to or below three feet, he augments the supply by turning handles controlling the sluice valves at the filters and permitting more water to pass. This man is supposed to regulate the flow from each filter bed, and it is left entirely to his judgment to turn on more water from one filter bed rather than the others ; the filters must be made to supply the pure water tank or the pumping must cease.

The water as filtered when I first visited the works was clear, bright and colourless.

Inside this "Pure Water Tank" is a small tank into which unfiltered water is passed to be raised by one set of engines to the filter beds. This matter will be referred to later.

Method of Working the Plant.—The pumps are kept at work day and night, but pumping ceases from midnight Saturday until 6 p.m. on Sunday, and again from midnight on Sunday until 6 a.m. on Monday, save in exceptional circumstances.

Rising Mains.—From the Waterworks the water is forced into rising mains. One main 16 inches in diameter, reduced to 15 inches in the High Street, takes the water up to the Cross Cliff Hill Reservoir ; a second rising main 12 inches in diameter carries the water to the West Gate Hill Reservoir. There is also a 4-inch rising main which does not discharge

into a reservoir. There are a few houses in the Bail and the North Gate Hill near the cathedral which can only be provided with water when the pumps are at work, as the reservoirs are not placed sufficiently high to supply all the City.

The rising mains are also the distributing mains, supplying the houses *en route*. If less water is pumped than is required for use in the houses, water from the reservoirs runs down to supply the deficiency. During the day the demand is greater than the amount pumped, but during the night the reverse is the case and the reservoirs are replenished. The town is thus supplied partly with water pumped direct from the Waterworks and partly from the storage reservoirs, except during cessation of pumping at the week end or for repairs, when the supply is entirely derived from the reservoirs.

Water mains.—Many of the mains and branch pipes laid down in 1847 are corroded and leaking: it is stated that so rotten are some of these old iron pipes that, when uncovered with a view to detection of leakages, they fall to pieces if lifted from the ground. Owing to some of the mains having to be laid in ground which is "shifting sand," advantage has been taken of the sewer manholes as a support, and in some instances the water mains are built into the brickwork of the manholes; in four instances, indeed, the water main is actually carried through the manhole. Occasionally, owing to the shifting of the sand, these water mains become broken, the fracture always taking place at the point where the main joins the brickwork of the manhole.

Circumstances associated with the Water Supply of Lincoln with reference to risks of pollution.—Between 1877-1880 the City was provided with a sewerage system. Dr. Harrison points out in his report of 1885 that the daily quantity of water required in Lincoln where water closets were becoming more in use was at least one million gallons, and he proceeds to show that the quantity available from the above-mentioned sources was not sufficient to supply the required amount. As regards the filtering area he states that, allowing for one filter to be out of use for cleansing, the beds could filter 2½ gallons per square foot per hour, or 1,148,040 gallons daily, "a quantity quite sufficient for the present wants of the City."

Dr. Harrison comments on the various sources of supply, and he furnishes in his report chemical analyses of the waters. Concerning the ballast pits, he writes:—

> This water is stated to rise up through a bed of gravel and sand, and gives good results on chemical examination.

The Prial Brook, which rises in Doddington Plantation, is about three miles in length. It drains a large tract of agricultural land and woods to the west of the City, and, after passing under the Doddington Road, flows into the Hartsholme Lake or Reservoir. At the time of formation of the lake the Prial Brook was deepened by excavation, and its banks were raised. Another source commences on the Doddington Road and passes into a lake at Stone's Place, the overflow from which flows into the Hartsholme Reservoir.

This water consists entirely of drainage from land and contains a large quantity of suspended matter.

Dr. Harrison analysed samples of the water from the Hartsholme Reservoir, the lake at Stone's Place, and from various parts of the Prial stream. He writes:—

> Not one of the waters, as taken, is fit for domestic purposes.

The Pike Drain commences about six miles from the Waterworks in the Parish of Eagle. It is formed by the junction of numerous ditches, or "drains," as the dykes constructed to drain the flat agricultural country in this part of Lincolnshire are called. The greater part of the water is derived from the drainage of arable land, but it also receives drainage from farmyards and surface water from roads. It crosses the road at Thorpe, and again near Hykeham Station, and for 600 yards skirts the side of the road from Lincoln to Newark, and after passing under the Doddington Road, enters the east end of a small lake at Boultham near the Waterworks. The outflow from this lake discharges into the River Witham near to and above the Waterworks. The intake from the Drain to the Waterworks is situated some 20 yards from the point where it enters the river.

The Pike Drain is unprotected throughout all its course. No villages drain directly into this drain, but there is no doubt that a large amount of filth would be washed into it after heavy rainfall.

Concerning the Pike Drain, Dr. Harrison writes:—

> I collected water at various parts . . . . along the course of this stream, and all the samples show signs of considerable contamination by organic matter.

The Catchwater Drain rises some distance beyond the village of Skellingthorpe (3½ miles from Lincoln), through which it flows, receiving pollution from farmyards and house drains, and washings from manured ground, and it is liable to contamination from cattle, geese and ducks. As it flows into the Witham it runs along the side of the Waterworks. The intake, a 14-inch pipe, from the Catchwater Drain, as it passes the Waterworks, was in existence in 1871, and was probably put in at a much earlier date. It is placed

some 200 yards above the outfall of the drain to the River Witham, and water from this source has been in use for many years. There is also at the Waterworks a by-pass through which water from the Catchwater Drain can be introduced into the City supply without passing through the filter beds. I am informed by the Water Engineer that this by-pass has never been used during his period of office.

In his report, Dr. Harrison dismisses the Catchwater Drain with the words :—

> Is liable to pollution, and the water does not give satisfactory results on analysis. This water, I understand, is not used.

As regards the River Witham, Dr. Harrison writes :—

> I have examined the river, and taken samples of the water at . . . various points . . . within a few miles miles of Lincoln the river is still so contaminated with unoxidized sewage as to be unfit for domestic purposes; and putting aside the unfavourable chemical condition of the water, a river receiving drainage and effluent from a large town (Grantham) could not with any degree of safety be used for domestic purposes. It is unwise and dangerous to take water from a source known to be polluted or liable to pollution, and trust to the purifying effects of filtration to render it safe for consumption.

It is clear that at times the River Witham provides the bulk of the water supply of Lincoln. Towards the close of the summer the Hartsholme water is cut off, and in the absence of any appreciable rainfall, the water in the Ballast Pits falls low, and little or no water flows down the Pike and Catchwater Drains. In the summer months the river is largely drawn upon, and as it supplies water to the Foss Dyke Canal, which leads from Lincoln to the River Trent at Torksey, when the water is drawn off for consumption in large quantity in the summer, it is necessary to pump water from the Trent into the Foss Dyke to make up for the water drawn off for the supply of Lincoln. It is said that at times when these pumps are at work, the flow of the river is reversed and that water from Brayford Pool, the point where the Foss Dyke joins the Witham, flows up stream to the Waterworks ; in these circumstances water from the River Trent might find its way into the City supply of Lincoln. The Foss Dyke is regularly traversed by barges, which come from the River Trent to Brayford Pool.

At the time that I first visited the Waterworks on 1st February, 1905, there was very little, if any, water flowing down the Catchwater Drain. It was stated that when the number of gallons pumped from this source exceeds the amount of the water coming down the Catchwater Drain, the flow of the water in the lower part is reversed, and the water from the River Witham flows up the Catchwater Drain and is pumped into the Waterworks. When I first saw this stream the water from the River Witham was distinctly passing up the Drain to the intake at the Waterworks. The same occurrence was observed at the Pike Drain, the River Witham water also supplying the bulk of the water entering the Waterworks at this intake.

At the Waterworks the water from the Pike and Catchwater Drains passes into small receiving wells and is raised by the pumps to a tank 8 feet by 4 feet by 5 feet placed at a height sufficient to allow it to flow to the filter beds by gravitation through a pipe 15 inches in diameter. If more water is pumped than can pass to the filter beds it falls back into the small tank or is returned by pipes to the receiving wells. The amount of water passing from the Catchwater Drain can be seen and can be gauged in one of these receiving wells, but that from the Pike Drain cannot, as it is piped to and pumped from a receiving well which is covered over and from which any surplus passes on to that well which receives water from the Catchwater Drain. The water from the Hartsholme Reservoir flows by gravitation, in a brick culvert, 24 inches in diameter, directly to the filter beds. This culvert is said to be in need of repair, and to leak ; possibly at times it may bring subsoil water to the Waterworks. At one part of its course it appears to be laid below a ditch which, until the second week of February, 1905, received drainage from Hartsholme Farm.

The water from the reservoir at Hartsholme is shut off in the summer months on account of the vegetable or gelatinous material which is brought down to and chokes the filter beds. The supply from this source is not resumed until after the first frosts of the season have freed the water from this material. The supply was cut off in May, 1904, and was not again laid on until February 23rd, 1905. Since that time the water from the Hartsholme Reservoir has been made to flow over a shallow weir at the Waterworks so that the amount entering can be gauged.

The water from the Ballast Pits flows by gravitation in an iron pipe, and joins the brick culvert from the Hartsholme Reservoir some distance from the Waterworks. The two ballast pits, Midland and Boultham, are connected with one another by means of an iron pipe which passes under the railway line. The outflow pipe is in the Boultham Pit which lies the nearer to Lincoln Waterworks. This outflow pipe cannot be seen, but its position can be approximately determined as the pipe passes to a brick chamber on the bank, the cover of which is kept locked. When I visited these Ballast Pits, Mr. Teague, the water engineer, informed me this chamber only contained a sluice valve for turning the outflow from the Ballast Pits on or off ; he had not the key with him at the time. It has since come to my notice that the water discharges directly from the Pits into this chamber, and is screened through a coarse sieve before it passes on in the pipes to Lincoln. Not far from the Ballast Pits, sand is being excavated for building purposes, and doubtless these excavations will become the receptacle of water which would otherwise find its way to the Ballast Pits.

I was informed that there was no means available for gauging the quantity of water coming into the Waterworks from either of these two last-mentioned sources of supply, but the amount passing from the Ballast Pits could have been gauged in the brick chamber; and that from the Hartsholme Reservoir can now be calculated as it flows over the weir at the Waterworks.

During my early visits to Lincoln, it was clear that nearly all the water pumped from the Waterworks was derived from the River Witham. The water from the Hartsholme Reservoir was cut off; that in the Ballast Pits was low and supplying but small quantity, and as the pumping had lowered the height of water unduly, this source of supply was stopped for a time on February 23rd, 1905.

Apart from the Hartsholme Lake, which may be considered in the sense of a storage reservoir, but from which water is only drawn during one portion of the year, and the Ballast Pits, there are no storage reservoirs, in which water can be ponded and undergo a process of self-purification by deposit of suspended matter, &c., before it passes to the filter beds.

The land traversed by the Prial Brook, and the Pike and Catchwater Drains is chiefly of a light sandy nature; it is highly cultivated and is at times manured with night soil and town refuse. Such material from Bracebridge Urban District is disposed of on a field about half a mile from the Ballast Pits.

The Pure Water Tank.—To select a place which is actually inside the "pure" water tank, for the construction of a tank intended to receive unfiltered water, and exhaust water from an engine room, is a procedure which seems devoid of wisdom. This inside tank, examined after the outbreak of the epidemic of enteric fever, seemed on superficial examination to be possibly not free from leakage.

The Waterworks Urinal and Closet.—At the Waterworks are a pail closet and a urinal for the use of the workmen. The contents of the pail are emptied by the workmen on land, cultivated as a vegetable garden inside the Waterworks enclosure, and dug in. The drain from the urinal passed between the filter beds and discharged into the Delph, a stream which ultimately empties into the Sincil Dyke. This drain was, as I understand, originally laid with open joints, which were afterwards cemented on the top, the bottom halves of the pipes, however, remaining uncemented. It also took the rain water from down spouts, the boilers, and an ornamental fountain. When tested in April, 1905, by the City Engineer, more water came out from the drain than went in from these sources. It is laid below the level of the floor of the filters, in sandy soil which is full of water, and apparently served also as a land drain; possibly should a filter bed leak, a fact not considered to be unlikely, the water thus flowing from the filter beds would find its way into this drain and, perchance, from the drain to the filter bed.

After the epidemic of enteric fever became established in the town, it was considered advisable to disconnect the drain at the urinal, and this was done towards the end of March or the beginning of April by the workmen at the Waterworks under the superintendence of the Water Engineer, and a new line of pipes, about a foot below the surface of the ground, was laid in a direction away from the filter beds, and carried round the engine-house and through two shallow chambers and connected with a pipe which was afterwards found to be the exhaust pipe of the engine. This drain was tested by Mr. Mortimer, the surveyor of the Branston Rural District Council shortly after it was laid down, and it was found that the drain was defective. It was uncovered the following day, when it was seen that the levels were not properly laid, and the joints not properly cemented; practically every joint leaked. I am informed that the urinal was afterwards drained to an unventilated cesspool.

It is hardly to be expected that workmen employed by the Contractor at the new boring now in process at the Waterworks would on all occasions resort to the urinal which is some distance from the place where they work. It has been reported that human excrement has been seen on the banks of the Catchwater Drain between the stream and the embankment which separates it from the Waterworks. I did not myself observe this, but on the side of the Catchwater Drain, remote from Waterworks, I noticed what seemed to be undoubtedly human fæces. This spot is easy of access not only from the Waterworks, but from the town, as one footbridge crosses the River Witham from the side of the Sincil Dyke to the confines of the Waterworks, and another crosses the Catchwater Drain as it passes the Waterworks and only a few yards distant from its outfall to the river. Moreover, on the Waterworks side of the river runs a public footpath, and the public have easy access to the locality.

Fisher folk.—Lincoln is a city to which anglers come from places connected with Lincoln by the railway. They arrive on Sunday mornings in large numbers from Nottingham and other large towns, as far away as Sheffield. They bring their provender for the day, and take up their positions for fishing along the banks of the River Witham, for the most part above the Waterworks intake. Doubtless they add to the pollution of the stream.

Cottages at the Waterworks.—Inside the Waterworks enclosure are two cottages for resident workmen. These have pail closets the contents of which are buried in the kitchen garden. Their slop drainage passes to a pipe which discharges into the Delph between the river and the Waterworks.

Situated on the banks, and nearer the source of the River Witham than the City of Lincoln, is the town of Grantham, which has a rateable value of £72,402, and had, at the census of 1901, a population of 17,593 persons. Grantham is distant from Lincoln 22 miles as the crow flies, but 35 miles by the course of the River Witham, and between Grantham and Lincoln, and on its banks are the following villages :—

Population of the Civil Parishes.					
140	...	Belton	Grantham Rural District.		
187	...	Syston	Claypole	„	„
413	...	Barkston	„	„	„
244	...	Marston	„	„	„
200	...	Hougham	„	„	„
153	...	Westborough	„	„	„
737	...	Long Bennington	„	„	„
		A cluster of houses at Claypole Water Mill.	„	„	„
542	...	Claypole	„	„	„
231	...	Barnby-in-the-Willows	Newark	„	„
272	...	Beckingham	Claypole	„	„
154	...	Stapleford	„	„	„
171	...	Norton Disney	„	„	„
614	...	Bassingham	„	„	„
109	...	Thurlby	„	„	„
84	...	Haddington	Branston	„	„
178	...	Aubourn	„	„	„
94	...	South Hykeham	„	„	„
551	...	North Hykeham	„	„	„

and the Urban District of Bracebridge (Population 1,700–1,800).

The Medical Officers of Health of the districts have furnished information as to the notifications of enteric fever in 1904 in their districts.

Claypole Rural District.—No case of enteric fever was notified in this district in 1904, but between the dates October 21st and 26th, inclusive, two young ladies visited the village of Long Bennington in this rural district and developed enteric fever on their return to Grantham Urban District and the Wheatley Urban District near Doncaster. The Grantham case is referred to later.

Grantham Rural District.—Three cases of enteric fever were notified in April, 1904, and the patients all resided in one house at Bitchfield, some miles from the River Witham.

Newark Rural District.—No case of enteric fever at the village of Barnby-in-the-Willows.

Dr. Berry, the medical officer of health for *Grantham Urban District*, informed me that the number of cases of enteric fever notified in the town was as follows :—

Year.	Number of cases of enteric fever.
1900	7
1901	12
1902	5
1903	3

In the year 1904 four cases were notified, one each on March 6th, June 6th, June 28th, and November 18th. The case notified on November 18th was that of a young lady aged 20, and the illness terminated fatally. She had, as has already been stated, visited Long Bennington, a village on the River Witham between Grantham and Lincoln, on October 21st, returning to Grantham on October 26th. She was attended in her illness by Dr. Berry, and he saw her first on November 9th, when she had already been ill some days. She was treated at her own home in charge of two professional nurses, and as soon as suspicion arose that the illness might prove to be enteric fever all excreta were disinfected before passing to the house drains, and the sewer was flushed daily.

No further cases were notified in Grantham Urban District until January 25th and February 3rd, 1905 ; this latter case was imported from Lincoln.

Grantham Sewage Farm.—The sewage farm of the Grantham Urban District is situated at Marston, four and a-half miles from Grantham, near the banks of the River Witham, into which its effluent from two outfalls is discharged. This sewage farm comprises about 110 acres of fairly flat land, almost sandy in character. It is underdrained, and the system adopted is downward filtration by broad irrigation ; there are some 40 acres of grass land, and seven acres of Osier beds. The amount of sewage treated per day varies between 800,000 and 1,000,000 gallons under ordinary circumstances ; in times of heavy rain this amount is considerably increased.

The manager of the farm is Mr. Wm. Preston Mason, who has been in charge since 1887.

At the time of my visit on February 9th the farm appeared to be well managed, and carefully worked, and the effluents as they passed from the outfalls were satisfactory

so far as smell, absence of colour and clearness were concerned. Indeed, the effluent passing into the River Witham compared favourably with the water flowing down the stream.

The greater part of the Bracebridge Urban District is connected to the main sewerage system of Lincoln, but part of the district is not thus connected. This latter portion, in which there are no water closets, is mainly on the banks of the River Witham. The household slop and surface water from the houses on both sides of the main street, together with the washings from the roads, pass by subsidiary drains to a main surface water drain, locally known as the Top Water Drain. This is a large earthenware pipe which empties into a ditch, which in turn opens into a dyke which, after skirting the back of Bracebridge village and taking additional surface and slop drainage, passes on to discharge into the River Witham about half a-mile above the Lincoln Waterworks. The sewage from the tramway depôt discharged into this surface water drain prior to the epidemic. This depôt, at which twelve men and eight boys are employed, and where some 22 horses are stabled, whose stalls drain to the common drain of the depôt, and where there is also a urinal and a vault privy, was taken over by the Lincoln Corporation in July 1904.

The drainage of the depôt was on January 28th, 1905, disconnected from the surface water drains, and therefore from the River Witham, and connected with the sewers. The ditch and dyke, which nobody appears to own and which were in a foul state, were cleaned out by the workmen from the Lincoln Waterworks on January 31st. The opening from the dyke to the river was then dammed with earth roughly placed across it, and the foul liquid flowing in ponded behind this temporary dam. A heavy shower of rain would probably cause the storm-water to carry away this dam, thus suddenly liberating to the river a large collection of foul material.

By the Lincoln Water Works Acts, 1871, it is in effect enacted that any person causing pollution of the various waters from which the Corporation derives its water supply is liable to a penalty of five pounds, and a daily penalty of twenty shillings for each day on which the offence continues. It was manifest on inspection of the water area that this power of the Corporation to protect its water supply against pollution has been very indifferently exercised.

Chemical and Bacteriological Examination of the Water.—When the deputation of the Corporation came to the Local Government Board on January 26th, 1905, they stated that a sample of the public water supply had been taken in the first week in January and submitted to analysis. The report, dated January 17th, is given in Addendum. It states that "from a chemical point of view the water is not fit for drinking," and that the total number of micro-organisms in this water is not excessive, but that the presence of intestinal bacteria must be regarded as evidence strongly suggestive of pollution with sewage or fæcal water.

Samples of water entering the Waterworks from the Catchwater Drain and Pike Drain and of the filtered water in the pure water tank were taken by me on February 1st and forwarded to Dr. Klein, who commenced his examination of them the same day. On February 11th some sediment from the pure water tank was sent to Dr. Klein. Details of his report on the examination of these waters are annexed. Briefly I may state that, as regards specific pollution, he found in the water of the Catchwater Drain a microbe "in all essential respects" the same as a laboratory specimen of Bacillus typhosus, and somewhat similar organisms in the water of the Pike Drain, in which water he also found a microbe corresponding with Gaertner's Bacillus. No microbe of this type was found in the water of the pure water tank; but in the sediment of the tank he found a microbe which was possibly the Bacillus typhosus, somewhat altered in its characters by sojourn in the water.

The water from the Catchwater and Pike Drains as it entered the Waterworks contained Bacillus coli communis in 1 c.c., but not in $\frac{1}{10}$th c.c.; that of the Catchwater Drain showed spores of Bacillus enteritidis sporogenes in 10 c.c., but not in 1 c.c.; and the Pike Drain water in 100 c.c., but not in 10 c.c. The number of microbes in the unfiltered water was 3,500 per 1 c.c., and 2,500 per 1 c.c. for the Catchwater and Pike Drains respectively. The filtered water only contained 64 microbes per 1 c.c., but it contained Bacillus coli communis in 1 c.c., although not in $\frac{1}{10}$th c.c. No spores of Bacillus enteritidis sporogenes were found in 100 c.c. of this water.

Meteorological conditions in the relation to the Outbreak.—Study of Diagram I. shows that during the second week in November, 1904 (6th-12th), rain only in small amount fell for five days. In the third week in November (13th-19th), there were three days on which there was frost. In the fourth week of November (20th-26th) rain and snow fell on four days and on six days there was frost, the thermometer dropping as low as 15° Fah. The temperature did not rise altogether above freezing point till the fourth day of the following week, November 30th. At this time the river and its contributory streams were frozen over. The frost broke rather suddenly, on the 1st December. There was frost again, the thermometer falling to 25° Fah. on December 9th, and much rain fell between that date and December 17th, when after a sudden rise of temperature the thermometer again dropped and there was frost for nine days.

It is to be borne in mind that heavy rainfall would wash into the streams and rivers the scourings of farmyards, and the refuse from the banks, whereby the water to be filtered would be to a corresponding extent polluted.

As I am informed the increased rate of pumping at the Waterworks commenced on November 19th, 1904, and continued till January, 1905.

Thus at a time when the water entering the Waterworks must have possessed a higher degree of impurity than usual, and when the filter beds were liable to be put out of working order by frost, a larger quantity of water than had previously been the case was being passed through the filter beds.

It has been the custom of the people of Lincoln to let the water flow from the taps during frost, in those cases where the water is laid on to exposed standards or pipes in the yards, and not carried inside the houses. Thus during a frost when the action of filter beds at both the Waterworks and sewage disposal works is liable to be prejudicially affected, a greater demand is imposed on them. I am informed that after a severe frost a month to six weeks elapses before all the burst water pipes and mains can be repaired and refitted, and in this interval much water runs to waste, and thus the demand for an increased amount of water in the City does not cease with the frost, but is continued during the period when the melting ice and snow carries impurities into the water; so that, at the time additional care in and a slower rate of, filtration are required, water is liable to be passed through the filter beds in undue amount and at an increased rate. As matter of fact, it was known that three of the filter beds were not working in a satisfactory manner in the last quarter of the year 1904.

If diagram I be again referred to it will be seen that the first case of enteric fever was notified just about three weeks after a frost which had been preceded by some rain. No source of the infection of the enteric fever had been traced in this case; but it is conceivable that some alteration had taken place in the filter beds at the Waterworks, either by the extra amount of water forced through, or from the action of frost itself, or by both of these means, which permitted insufficiently purified water to pass through the filter beds.

The second case of enteric fever notified on December 22nd, was followed four days later by a batch of cases 16 in number, the notifications extending over the period of 12 days (27th of December to 7th of January). A month before this second case occurred, with the cases that immediately succeeded it, there had been rain in considerable amount with snow and severe frost which broke up rapidly three weeks before these cases were notified. It is possible that the alteration the filter beds may have sustained, as suggested above, may have become exaggerated, and that pollution in greater amount than before may have gained access to the water as delivered from the Waterworks.

For a third time these conditions are repeated, almost in the same order during the period from December 7th to December 31st, snow, with frost, heavy rains and rapid thaw, followed by severe frost and again rapid thaw. A batch of eight cases of enteric were notified between January 12th and 18th, and three weeks after the thaw of the last week in December was well established, came the great outburst of enteric fever which rose suddenly during the fourth week of January, attained its greatest altitude during the first week in February, and which fell, not quite so quickly as it rose, during the second and third weeks of that month.

Discontent as to the source of supply prior to the Enteric Fever outbreak of 1904-5.—The unsatisfactory nature of the source from whence the water is supplied to the City of Lincoln has from time to time been brought to the notice of the Corporation by the Local Government Board.

After a letter from the Board to the Corporation in 1885,* and during the prevalence of cholera on the Continent of Europe in 1886-7, Dr. Airy, one of the Medical Inspectors of the Local Government Board, visited and inspected Lincoln in October, 1886, and left with the Corporation a memorandum of recommendations for their guidance, the first of which referred to "The unsafe character of part of the public water supply and the need "of inquiry concerning other possible sources of supply."

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* 50547 K²
1885.

LOCAL GOVERNMENT BOARD,
11th June, 1885.

H. K. HEBB, ESQ.,
Clerk to the Lincoln Urban Sanitary Authority, Lincoln.

SIR,

I am directed by the Local Government Board to state that they have had under consideration your letter of the 16th instant, together with the report made by Dr. C. Harrison, the Medical Officer of Health for the City of Lincoln, with reference to the water supply of the City, and I am to state that having carefully considered the papers submitted to them, the Board cannot agree with the Town Council that "the quality of "the water supplied by the Corporation does not afford reasonable grounds for complaint."

It seems to the Board that the Town Council will incur a grave responsibility if disease should hereafter spread in the City through preventable pollution of the water supply.

I am, etc.,
(Signed) S. B. PROVIS,
Assist. Secy.

Correspondence on this subject ensued between the Board and the Corporation, but beyond obtaining two reports (December 15th, 1886, and September 13th, 1887) from their Water Engineer, the Corporation appear to have done but little in the way of dealing with the water question on the lines of Dr. Airy's recommendation.

At the time of the threatened invasion of this country by cholera in 1893-4, the City of Lincoln was inspected by my colleague, Dr Wheaton, early in May, 1894. On the 29th May of that year, he met the Corporation of Lincoln in conference. The Mayor, A. W. Hall, Esq., presided at the meeting; there were present Aldermen Maltby, Glasier, Dickinson, Williamson, Councillors Page, E. Pratt, Harrison, Wallis, Woodcock, Pacy, Lowe, Ellis, Turner, Brogden and Martin, and several officers of the Corporation.

At this conference, Dr Wheaton made a series of recommendations to the Corporation as regards measures to be taken with a view to dealing with cholera and other dangerous infectious diseases. He left with the Corporation a memorandum of the recommendations and this is affixed to the Corporation Minutes recording the conference.

The first recommendation is worded as follows:—

1. *Water Supply.*—The Sanitary Authority should endeavour to obtain a supply of water from a source which is above suspicion for their district in place of the present supply. In the meantime, pending the provision of a suitable supply, every means should be taken to prevent the pollution of the water and also to ensure its efficient filtration before distribution.

In his report to the Local Government Board as to the proceedings at this conference, Dr. Wheaton states:—

With regard to Recommendation No. 1, concerning the water supply, I referred to the dangers connected with the use of water from sources which were liable to pollution from sewage and manure; and said that filtration could not be relied upon as a safe guard in the use of such water. I mentioned outbreaks of cholera and of enteric fever, which had been attributed to the use of water similar in source to the Lincoln supply, although previously subjected to filtration. I referred to the great difficulties met with in carrying out efficient filtration; especially when the water to be filtered was derived partly from a river and partly from arable land; as is the case at Lincoln, owing to the large amount of suspended matter in the water after rainfall clogging the surface of the filter beds, in the absence of any subsidence reservoir, except in the case of the water of the Prial Drain, which does flow into a reservoir before passing into the filters. The water of the Prial Drain, however, as mentioned in my report, cannot be used after the beginning of June, owing to its becoming foul in the reservoir. I referred to the method of renewing the filter beds, as tending to cause inequalities in the rate of filtration, by causing a dangerous thinning of one end of the filter bed. I also referred to the absence of any provision for excluding from the general supply the first portion of water which passes through the filters after the renewal of the filtering material. I also drew attention to the dangers associated with the effect of frost upon the filter beds which are uncovered. I advised the Sanitary Authority to obtain a supply of water from a source which was quite free from risk of pollution, and which would not require filtration in order to remove organic matter from it. I said that the comparative exemption of the City of Lincoln from cholera and enteric fever during recent years should not be allowed to create a false sense of security, and that it was of no use to wait until an epidemic occurred before obtaining a supply of pure water. A great deal of discussion took place upon this recommendation. It was said that the absence of evidence of any effect of the present water supply in causing disease during recent years, made it probable that such exemption would continue and that in any case, although the water was not a "first-class" water, still this risk was not too great to be run. It was said that London was satisfied with a water supply of a similar nature, and obtained from similar sources, and which had been pronounced by the Royal Commission on Metropolitan Water Supply to be of a "very high standard of excellence and purity"; and that the Commission had declared that there were dangers associated with the use of a water which was "too pure." I was asked whether I thought that a fresh supply of water was so urgently required that it should be provided regardless of cost. To which I replied that this certainly was the case.

The Lincoln Medical Society in 1897 directed the attention of the City Council to the unsatisfactory source from which the water supplied was derived, and some correspondence ensued, the Corporation indicating that they did not agree with the criticisms of the Medical Society.

The Medical Officer of Health in his Special Report on the Water Supply of Lincoln in 1885, placed on record his opinion (cited on p. 23 of this Appendix) as to the want of wisdom of relying on the filtration of water from a polluted source, and realizing that efficient filtration alone stood between the people of Lincoln and water-borne disease, he has from time to time in his Annual Reports called attention to the need of extra filtration areas as the amount of water consumed in the City became larger. In his Annual Report for 1891 he drew attention to an outbreak of severe diarrhœa in the January of that year which was confined to persons, mostly adults, who were resident within the area supplied with water from the Lincoln Corporation Waterworks. He states that these attacks were followed by extreme prostration, but no deaths were registered from the diarrhœa. At the time of the outbreak the supply was chiefly from the River Witham, which had for some weeks been frozen. The water was turbid, and had an offensive smell when heated, and contained a large excess of organic matter.

Attempts of the Corporation to obtain additional Water Supply for Lincoln.—Even before the epidemic of enteric fever in 1904-5, the subject of the water supply has occupied much of the time of the Corporation in discussion. There have been members of the City Council who realized the risk the City ran from continuing the use of water derived from polluted sources, but the stalwart supporters of the existing supply, who have always been ready to oppose their opinion to that of "experts," have, beyond receiving reports on its nature and on additional sources which might be made available, succeeded in preventing anything like comprehensive action being taken until comparatively recent years.

Nevertheless, these reports received by the Corporation has shown the difficulty and the uncertainty of procuring water in amount required for a large City like Lincoln, and the plans that have from time to time been suggested have generally had for their object the supplementing of the existing supplies rather than their supersession. The success of most of the schemes depended on the chance of a sufficient amount of wholesome water being obtained as a result of deep boring into Sandstone or Limestone; a problematical event which may have led the Corporation to hesitate to incur the heavy cost involved.

In 1891 the Corporation consulted Mr. C. E. de Rance, M.Inst.C.E., as to the possibility of providing a fresh supply of water for Lincoln. His report deals with the geology of the district, and he expresses an opinion that a boring down to the Red Sandstone in the neighbourhood of the City would produce a million gallons a day. He gives an alternative scheme—the sinking of shafts and adits in the Limestone nearer the City, whereby "a variable quantity necessitating storage" could be obtained.

Following on the outbreak of enteric fever at Maidstone and the protest of the Lincoln Medical Society, the Corporation in 1898 consulted Professor Edward Hull, LL.D., who was asked to advise as to a supply of water for the City, and he furnished a report in October, 1898. He sets forth three schemes, and decides in favour of one—the sinking of a well 200 feet in depth, and the driving of a bore-hole into the Sandstone from the bottom of the well of such diameter that it should not be less than twelve or fourteen inches in diameter at a depth of 1,200 feet from the bottom of the well.

From this boring it was calculated that 1,000,000 gallons of water per day would be obtained from a depth of 1,900 feet. It is clear that this supply was only considered as supplemental to that from the Witham, as Professor Hull writes:—

> The water pumped might be mixed with the existing supply from the River Witham.

In 1898, the Corporation determined to improve their water supply, and, although some considerable time elapsed between the date of the receipt of Professor Hall's report and the actual date of commencing the boring, the Minutes of the Committee show that the matter was in no way shelved, many important details had to be investigated and dealt with before the Corporation was in a position to cause the boring to be undertaken. After the report was considered, estimates for the borings were asked for and waterworks visited. In July, 1899, Mr. Percy Griffiths was appointed as the Engineer for the Corporation in connection with the contemplated works. After consideration of tenders this plan was adopted, and in August, 1901, a contract was signed with Messrs. Chapman and Sons, of Salford, for £14,605, the main portion of the work was to be completed in four years, and the bore was commenced at the Waterworks.

Operations were interrupted in November, 1903, by the jamming of the boring tool in the borehole, and by the breaking of a rope with the loss of the boring tool at a depth of 860 feet. The tool became embedded in the boring and attempts to recover it failed. The brick well-shaft, 9 feet in diameter, which had been sunk to a depth of 400 feet from the surface was continued to a depth of 890 feet, thus increasing the facilities in boring. The contractors then applied to the Corporation for financial assistance, and it was resolved to make advances to an amount equal to the contractors' actual expenditure in constructing the well. The borehole, 30 inches in diameter, was recommenced from the bottom of the well; also by means of this well-shaft the size of the borings can be continued at an increased diameter beyond that originally agreed upon. It is considered that the Sandstone will be reached at a depth of 618 feet below the level of the bottom of the well-shaft, but some months must elapse before this work is completed, and there is always the risk of the rope again breaking if the boring diverges from the direct line, and the boring tool, an instrument some ten feet in length, gets jammed in the bore.

The epidemic of enteric fever thus occurred at a time when steps were actually being taken to improve the existing supply of water to the City, but before any advantage could be reaped from the work in hand.

On February 18th, 1905, the Special Committee of the City Council decided to seek the assistance of Mr. Geo. H. Hill, the Water Engineer of Manchester, who designed and carried out the Thirlmere Waterworks, and who was a member of the Special Commission for dealing with the London Water Supply, in improving their existing Waterworks, and in seeking a supply of water from some source other than the River Witham. Mr. Hill suggested that the advice of Mr. Wm. Whittaker, B.A., F.R.S., Past President of the Geological Society and of the Geological Association, should be sought, and this gentleman, at the request of the Special Committee, met them in consultation on February 22nd. Mr. Henry Preston, Manager to the Grantham Waterworks, who has made special study of the Geology of Lincolnshire, was also associated with Messrs. Hill and Whittaker in this inquiry.

The difficulty of obtaining water in amount required for Lincoln is again emphasized by the reports of Mr. William Whittaker on the underground sources of supply; and by Messrs. George H. Hill & Sons, on the question of boring, and the latter also sets forth estimated cost of the undertaking.

Briefly, they show that to obtain water by deep boring from a selected site would cost an outlay of some £100,000, and between £8,000 to £9,000 annual working expenses ; a sum when capitalized of about £300,000. Moreover, several years would probably elapse before the water would be available for the supply of the City.

The Chemical Treatment of the Water.—At my first meeting with the representatives of the Corporation, on January 31st, I suggested that the Corporation should cause water to be boiled in bulk and distributed by carts throughout the poorer parts of the City. This suggestion was regarded as impracticable, and I was informed that the artizan population as a whole was an intelligent class and would boil their water after reading the notices posted in the City by the Corporation. As regards the lower grade population, it was stated that, even if they could be induced to receive boiled water from the Corporation carts, they would not use it, and would probably throw it into the streets.

To supply Lincoln at short notice with some 2,000,000 gallons of water a day from a source above suspicion was out of the question.

I therefore suggested, on February 7th, to the Committee the desirability of consulting with experts in bacteriology and chemistry with a view to treating the water supplied to the town, so as to render it reasonably free from the Bacillus typhosus. The Committee accepted this suggestion and, in relation therewith, sought the assistance of Drs. Houston and McGowan, of whom the former has been engaged in the study of the biology of water for many years, and is the bacteriologist, as the latter is the chemist, of the Royal Commission on sewage disposal. Dr. Houston arrived in Lincoln on February 8th, and Dr. McGowan on February 9th, and, after study of the local conditions, commenced the treatment of the water on February 11th.

The difficulty in treating the water of Lincoln with any chemical is due to the fact that, excepting the reservoirs at Cross Cliff Hill and Westgate holding between them about one day's supply of water, and to which the water is pumped after filtration, there is no storage reservoir where any process of water sterilization on a large scale could be carried out before filtration without cutting off the supply to the City. In determining the manner in which any process intended to secure the sterilization of the public water supply would best be applied, several circumstances had to be borne in mind. Inasmuch as the Bacillus typhosus had been found in the water passing into the Waterworks from the Catchwater Drain and the Pike Drain, water derived in all probability from the River Witham, there was strong presumption that the filter beds were infected. This consideration, coupled with that of the presence, established at a slightly later date, of a modified form of Bacillus typhosus in the sediment of the pure water tank from which the previously filtered water is pumped direct to the City, showed the necessity of disinfecting the filter beds and the pure water tank, and of treating the water prior to its filtration.

Drs. Houston and McGowan, after study of the local conditions, came to the conclusion that the addition of chloros (a commercial preparation of the hypochlorite of soda, of which they had had previous experience in experimental sterilization of sewage effluents) to the water as it passed to the filter beds afforded the best chance of rendering the water free from objectionable micro-organisms and at the same time devoid of harmful properties to the consumer.

This treatment was commenced on February 11th, and was thenceforth applied continuously to the water passing into the works from the River Witham (Catchwater and Pike Drains). The water from the Ballast Pits was not dealt with as it was regarded as free from suspicion, and the water from the Hartsholme Reservoir was not in use at that time.

The water in the service reservoir at Cross Cliff Hill was treated on February 11th, 13th, 18th and 20th, and that in the service reservoir at Westgate on February 12th, 14th and 17th. These reservoirs were dealt with at night, so as to interfere as little as might be with the demand of the City for water, and to give time to permit of the water being under treatment for some hours before it passed into supply.

The carboys containing chloros were arranged so that by siphon action the chemical could drop continuously on to the water as it was pumped to the filter beds. The filter beds themselves were treated with chloros, and the pure water tank was emptied and disinfected.

To prevent any possibility of free acid passing into the supply a few pieces of chloride of calcium were placed in the pure water tank, and by way of test a live gold fish was kept in this tank. The water, during the earlier periods of the treatment, was tested chemically with iodide of potassium and starch to detect any minute quantity of chlorine which might pass through the filters into the supply, and samples of water drawn from different parts of the City were tested for the presence of minute quantities of lead ; no trace of this metal was ever found. Daily biological examination was made of the water after treatment ; the results obtained were remarkably good.

The Bacillus typhosus and the Bacillus coli communis are both microbes found in discharges from the intestine, but the former is a less hardy organism than the latter and more readily perishes when exposed to uncongenial surroundings. This fact is taken advantage of in dealing with the purification of sewage effluents and water polluted with organic material of intestinal origin.

It is known that an agent or condition which will destroy or materially diminish the number of Bacillus coli communis present in a given sample will, with certainty, kill the less robust Bacillus typhosus. Also because the Bacillus coli communis is constantly present in sewage, its presence in larger or smaller amount in a water is taken as an index of the degree of pollution of that water, and therefore of the potential risk incurred in using such water for domestic purposes. Hence the smallest quantity of water in which the Bacillus coli communis can be detected is taken as the standard of purity of the water in question. The result is expressed in terms of cubic centimetres (c.c.).

The water at Lincoln after treatment with "chloros," though quite clear and free from turbidity, had a distinctly musty smell and taste. When the water was hot or cold this smell and taste were not markedly appreciable, but when the water was merely warm the odour given off could not fail to be detected by persons having *ordinary* sense of smell. After some weeks of treatment either on account of the organic matter present in the filter beds being used up, oxidized, or on account of the lesser quantity of chloros used, this smell and taste became less, and in the first week of May I could not detect it. The scent given off from the water somewhat resembled that of nuts in an earthenware vessel which had been brought up from storage in a damp cellar. Nevertheless although to the senses of sight, smell and taste the water compared favourably with the waters supplied in many places from upland moorland sources, the people of Lincoln, accustomed to a tasteless water, and having the knowledge that the water had been treated with " chemicals," refused in many instances to drink it.

In the Corporation notice warning the people that the water had been submitted to chemical purification, it was stated that the water had better be boiled before use.

This statement drew forth the criticism that if it were still necessary to boil the water before use, why should it also be treated chemically ?

The proportion in which chloros was added to the water varied from time to time with the varying circumstances, and with the further knowledge brought by experience. At the commencement, one part in 10,000 was used at the Waterworks, but it was found that one part in 20,000 shut up in a filter bed until its presence in the water percolating through could not be detected by the iodide of potassium and starch test (which is said to be capable of detecting one part in two millions), was of sufficient strength to sterilize the filter bed. The strength of the chemical added in the first instance to the incoming water was 1 to 10,000 ; and to the water in the reservoirs, as estimated on their maximum capacity, the strength at first added was 1 in 64,000 at Crosscliffe and 1 in 100,000 at Westgate, but as neither reservoir was full of water at the time, the proportions were somewhat higher.

This strength was reduced on February 21st to one part in 50,000 before filtration, and at the reservoirs to one part in 100,000.

When sodium hypochlorite is added to water, oxygen is liberated and in its nascent form acts as a powerful oxidizing agent, and common salt (sodium chloride) is formed. At the strength the chloros was used the amount of common salt formed would be extremely small, and could not be detected in the water, except by chemical tests.

On February 24th the members of the medical profession practising in Lincoln, some 30 to 40 gentlemen, were invited to meet Drs. Houston and McGowan and myself in conference. At this meeting I explained the difficulties that had to be dealt with, and the action adopted. It was stated by certain of the medical men present that the water as treated, had caused colic and diarrhœa among their patients and eczema, skin irritation, and conjunctivitis. Others had noticed nothing of the sort. This irritant action was considered by a few to be due to " chlorination " of the water, but it was pointed out that chemical tests capable of detecting free chlorine in one part per two million failed to show any trace of chlorine in the water—and it was admitted by certain of these practitioners that they treated their enteric fever patients with chlorine mixture. The medical profession was divided in opinion as to the quality of the water supplied by the Corporation Waterworks, but they were unable to suggest any alternative treatment.

It is difficult to understand how, and in what manner chloros which could not be, detected in the water as supplied to the City by the most delicate tests, could have affected certain persons in the manner attributed to it. It is known that a man drank daily half a pint of a 1 in 5000 solution of the crystals of sodium hypo-chlorite, which contained about 37 per cent. by weight of available chlorine, for a period between two to three weeks without experiencing any ill results ; and this solution would not have become "spent," as would the chloros in acting on organic material present in the Lincoln water.

Water brought into the District from places outside.—As soon as it became known that the water supplied by the Corporation from the Waterworks was specifically contaminated, the demand for a water from another source arose in the town. At the beginning large numbers of persons fetched their drinking water from the drinking fountains supplied with conduit water, but on the 16th February, 1905, as a result of a Corporation notice as follows :—" Water from the conduits is not free from risk, as the ground above the head " of the springs is heavily manured. If consumed it should be previously boiled,"—the use of water from this source of water supply was in great part discontinued.

On and after February 17th, 10,000 gallons of water were brought into the town daily from Newark by the Midland Railway through the generosity of Alderman T. Smith of Newark, the public being allowed to draw water from the tenders in the railway yard. The water tanks of the tenders were joined up to an arrangement of pipes which allowed several taps to be in use at one time. This supply was subsequently, on the 25th February, increased by another 10,000 gallons a day at the expense of Mr. Sharpley Bambridge, J.P., Councillor of Lincoln, and the cost of further quantities was defrayed by the Mayor of Lincoln and Messrs. Hole and Co., of Newark. The water provided in this way was distributed to all parts of the City by the Corporation, notices being issued as to the times and places at which the water could be procured. A daily supply of some 20-21,000 gallons was available till March 31st, 1905. On April 1st, the Great Northern Railway commenced to carry to Lincoln at their own expense 30,000 gallons a day from their waterworks at Willoughby near Alford, the Corporation having to pay only the cost of delivery in the City. The Company undertook to maintain this supply for two months. Under arrangements made by the Relief Fund Organization, Corporation Watercarts, holding 450 gallons each, brought, for some few days, water into Lincoln from Welton, a village six miles distant, but this supply was discontinued in the second week of March, as the water did not yield good results on chemical analysis. Water was also brought into the town by rail in jars from Market Rasen.

Many persons made their own arrangements for a supply of drinking water from the neighbouring villages. Little inquiry was made as to the sources from which these waters were derived, and when made as to its degree of wholesomeness, it was limited to a chemical analysis of the water. So long as the water was stated to be from a source other than the Lincoln Corporation supply there were people ready to buy it from hawkers in the streets at 2d. a gallon.

The use of Well-water.—Many of the old wells of the City were re-opened, and samples of their waters sent to the Medical Officer of Health for analysis. The samples were forwarded to the Public Analyst of the Corporation, Mr. Baynes, at Hull, who made chemical analyses of them, which showed that the waters were, chemically, fairly good drinking waters. No biological examination of these waters were made, and they were taken into use on the report of the chemical analysis. The water from a spring by the new schools on Monks Road, which yielded satisfactory results on chemical analysis, was afterwards condemned by the Corporation Analyst on his subjecting it to biological examination.

Examination of Men at the Waterworks.—There are 13 regular men and some casual labourers employed by the Corporation at the Waterworks, and the contractor sinking the new boring inside the Waterworks enclosure has employed on the average 34 men, who have worked day and night in eight-hour shifts. It occurred to me early in the epidemic that possibly one of these men might have passed through a mild attack of enteric fever and be suffering from "typhoid bacilluria," as it seemed probable that the number of "Bacillus Typhosus" present in the water was in excess of what might have been expected from pollution of a river water by enteric fever stools, unless perchance the bacilli had increased in the water; and there is reason to believe that Bacillus Typhosus not only does not increase, but, on the contrary, perishes in a short time. The presence of "typhoid bacilluria" in a workman, who would have abundance of opportunity of passing his urine into the river in close proximity to the Waterworks, might be held to account for the large quantity of the bacilli found in the water.

With a view to eliminate this possible source of specific pollution I asked that the blood of the workmen should be submitted to Widal's test, and that if any reacted to the test, their urine, together with the urine of such men as refused to submit to the taking of the few drops of blood necessary for examination for the Widal reaction, should be biologically examined for the presence of the Bacillus Typhosus. This examination was, through a misunderstanding, only partially carried out. Blood of 38 of these workmen was submitted to Widal's test, and of these three gave some reaction, the urine of these three men being subsequently examined for the presence of B. typhosus, with a negative result in each case.

Bracebridge Urban District.—There are now some 446 houses in this district, some 76 houses having been built since the census of 1901 was taken. Of these houses, 425 are on the Lincoln water supply, those not on the supply being scattered houses in the southern portion of the district.

Branston Rural District.—The whole of that portion of the district known as New Boultham is on the Lincoln water supply, and this water is also laid on to some 25 houses outside this special area.

APPENDIX 2.

Sewerage and Drainage.

The City of Lincoln.—For many years some of the sewage in drains from water-closet and cesspool found its way into street channels and, with the surface water, discharged either to the River Witham in its passage through the City, or to the Sincil Dyke. Lincoln was, indeed, without a system of sewers until a scheme of sewerage was carried out in 1877–80 by Messrs. Lawson and Mansergh. This scheme was the result of Writ of Mandamus of the Local Government Board in 1876. The Mayor, Aldermen and Citizens of the City of Lincoln were commanded by the High Court of Justice to obey the Order of the Local Government Board dated March 8th, 1875, which required the Corporation to provide their District with a proper system of main sewerage.

The sewers, and the sewage farm of the City of Lincoln are under the supervision of Mr. R. A. McBrair, the city engineer, who was appointed in 1881.

Considerable difficulty was experienced in laying the sewers in certain parts of the City, as the ground in places proved to be shifting sand, and foundations had to be made for the sewers to rest on. In one or two instances it has been found that the sewers had broken and the sewer pipes had absolutely disappeared in the sand, and wooden piles had to be driven down and iron sewer pipes substituted for the older earthenware ones. It is said that the men engaged in this work had to constantly shift their foothold to avoid sinking into the sand.

Separate systems were laid down for the sewage and the surface water. But, with the extension of the City, the rain water from the roofs of houses of the artizan dwelling type and from out-buildings, *i.e.*, outside water-closets, coal sheds and sculleries, was allowed to discharge to the sink gullies in the yards, and in this way now gains access to the sewage-sewers; so that a large quantity of rain water finds its way to these sewers, which were never intended to receive it. It has thus come about that at times of heavy rain the sewage-sewers are unable to carry off the flood water at once, with the result that sewer-contents are forced up the manholes and sewer ventilators in the lower lying parts of the City.

Moreover, the City sewers now also receive sewage from the Bracebridge Urban District, from the suburb of Lincoln, New Boultham, in the Branston Rural District; from the Barracks, and, since February 3rd, 1905, the effluent from the Bracebridge Asylum sewage farm.

Description of Sewage-Sewers.—There are 42 miles of main sewers in Lincoln.

There are about 2¾ miles of brick egg-shaped sewers, varying from 2 feet 6 inches by 1 foot 8 inches to 3 feet 6 inches by 2 feet 4 inches. They form two main sewers which receive the sewage from the northern and southern portions of the town respectively. These main sewers converge to a large underground chamber, situated about a mile to the east of the City, in which the sewage collects, and whence it is pumped to the sewage farm, situated at Canwick. The sewage is raised 60 feet from the pumping station to the sewage farm. The remainder of the sewers are pipe sewers, varying from 24 inches to 6 inches in diameter, the usual size of main sewer in the side streets is 12 inches. Ventilation is provided for the sewers, by surface gratings in the streets and by ventilating shafts of iron piping. These latter are in the central parts of the City where the surface gratings have been closed, and the ventilating shafts (218 in number), of 6 inches and 4 inches in diameter, have been fixed. There are six automatic flushing chambers, their capacity varying from 600 to 1,370 gallons, placed on the main sewers. In addition flushing is carried out by water from standpipes in the streets or from water carts. All the sewers are flushed once a fortnight in winter and once a week in summer, and, during the enteric fever epidemic, all sewers were flushed once in four days, a considerable amount of disinfectant being added to the water. All the dead ends of the sewers can be flushed. The sewers vary considerably in gradient, and there is but little fall on some of them; they are not all self-cleansing and deposit at times takes place in certain sewers.

House Drainage.—The house drains are generally 6 inches in size, mostly jointed in cement. Those of the better-class houses are provided with inspection chambers and traps; but for the remainder, which is by far the greater part, there is no inspection chamber and only one trap. In these latter cases, however, the water-closets are outside the houses in the yards. House drains are ventilated with pipes 4 inches in diameter, but these are not always carried up straight without bends. The sink and bath waste pipes are properly disconnected. Such defects in the drains of old property as come to the knowledge of the Sanitary Authority are promptly remedied.

The by-laws with respect to new streets and buildings in force in the City were allowed by the Local Government Board on September 11th, 1880. In By-law No. 70 it is definitely stated that there shall be a suitable trap on the house drains, but the Corporation on September 6th, 1881, made other regulations in which to the by-law No. 70 is added, "unless otherwise allowed by the Corporation." This regulation was made under Section 21 of the Public Health Act, 1875.

In the opinion of the Board the By-law No. 70, which does not reserve any discretionary power to the Council, will have effect in as far as it affects new buildings, notwithstanding any regulations under Section 21.

Excrement Disposal and Removal is chiefly effected by means of water-closets, which, as previously stated, are generally situated outside the houses. These closets, usually of the flush-out type and well constructed, are provided with separate cisterns, but in the poorer house property they are not always properly looked after by those who have the use of them.

At one time Lincoln was a town of cesspools and privies, but when the system of sewerage was laid down these were gradually abolished and water-closets substituted ; but there are still about 500 privy vaults and 250 pail-closets. The latter are emptied weekly ; the privy vaults are emptied on notice being sent to the Corporation Offices.

Scavenging.—Six men, with three carts and three horses and some 26 sweepers, including orderly boys, are employed in road scavenging. The road scrapings are taken out of the town by barges, and together with the night soil from the existing privies is disposed of for manure on farms in the rural district. In consequence of the conversion from privies to water-closets, it has been found possible to reduce the staff engaged in the removal of night soil to three men, and only one cart is now used.

Refuse Disposal.—The City possesses no refuse destructor. Some 40 men, 20 horses and 20 carts are employed to collect the house refuse. Part of the refuse is burnt on the West Common with the view of raising low-lying swampy ground, part is tipped on land at Boultham, part disposed of in an old stone quarry on the Wragly Road, and part in a brick pit on the Benton Road ; these last three places are all in the suburbs.

Description of Lincoln Sewage Farm.—The area of the sewage farm at Canwick is 66 acres, of which 31 acres underdrained.

The pumping plant was erected and the farm laid out between 1877-1881. There were six settling tanks, holding 940,000 gallons. The pumping commenced in 1881, and the crude unsettled sewage, passing through a rising main and siphon, was run directly on to the farm. The use of the siphon was given up in 1887, as sewage sent thereby could not reach the settling tanks. In 1882 mechanical subsidence of the sewage without precipitation was commenced, and lime was added to it in 1886. In 1888 filter presses for the sludge were introduced, and in 1889 the precipitant was altered to sulphate of iron, 1 grain and lime 3·7 grains per gallon ; also in this year lime kilns were built on an adjoining farm belonging to the Corporation, who then began to make their own lime. This treatment was discontinued in 1896, and after trying ferrozone for a few months, alumino-ferric was adopted, and this was used, except for a short time in 1899 when ferral was substituted, until the end of 1903. Some polarite beds, 2,100 square yards, were constructed in 1896 ; and in this year, the presses being found inadequate to deal with the growing quantity of sludge, part of it was run through 6-inch iron pipes to the fen and there dug in. No sludge was pressed after 1899, all the sludge being sent into lagoons in the fen.

In 1898 the first bacterial beds were commenced, and construction of these beds was continued until the end of 1903. In 1900 two open concrete slab channels were constructed from the railway arch to the Sincil Dyke, with a view to aerate the effluent during its passage to the outfall into the Sincil dyke. In 1902 two additional settling tanks, having a total capacity of 590,000 gallons, were constructed, and a small experimental continuous coke filter was erected, which has been in continual use to the present time.

The volume of sewage to be treated has been continually increasing, and when in 1903 the bacterial beds were completed, they were barely sufficient for receiving and treating a day's sewage, and they were without any "stand by" for use in emergency. An additional settling tank was added, having a capacity of 350,000 gallons, thus bringing the total capacity of all the settling tanks up to 1,880,000 gallons. When this was done the use of alumino-ferric as a precipitant was given up.

In 1904 an open channel 12 feet wide was laid down from the point where the Washingborough Road crosses the sewage farm, to join the open channel from the railway arch to the Sincil Dyke : and by the side of this open channel as it crosses the fens a pipe 15 inches in diameter was put in to permit the effluent being discharged into the Sincil Dyke in flood time, when the water in the dyke rises some feet above its normal level.

The sewage under ordinary circumstances is pumped from the Pumping Station between the hours of 5 a.m. and 8 p.m. but in the early months of 1905 it was found necessary to pump till midnight. In times of flood the pumping is continuously carried on day and night. The sewage is allowed to remain in the settling tanks 12 hours. It is

drawn off day and night successively into the bacterial beds, and after two hours' rest in the beds, the effluent is discharged into the Sincil Dyke. The few inches of sewage lying above the sludge and below the level of the pipes delivering to the bacterial beds, after 12 hours' rest, is sent on to the farm for land treatment.

At the end of 1904 the capacity of the settling tanks was 1,880,000 gallons. There were 13 bacterial beds filled with coke to a depth of 5 feet to 5 feet 6 inches ; and this coke has remained unchanged during the whole time the beds have been in use. The first bed was built in April, 1898, and the last in November, 1903. The area of the primary beds is 8,274 square yards and the secondary 7,233 square yards, 3·20 acres. The polarite beds are only used when the bacterial beds are resting. The total capacity of the bacterial beds in May, 1904, was 1,427,500 gallons, and this on April 6th, 1905, had become reduced to about 1,300,000.

The quantity of sewage to be treated, however, has steadily increased. The average daily quantity of sewage pumped for the year ending March 31st, 1903, was 1,350,000 gallons ; and that for the year ending March 31st, 1904, 1,529,533 gallons. It is now seen that the Corporation would have done better if they had not stopped building bacterial filter beds at the end of 1903, and additional filter beds are now under construction.

The effluents from the bacterial beds and from the land under broad irrigation, discharge by two separate outfalls to the Sincil Dyke, and there is a third outfall to the dyke from the sludge lagoons. At the time of my visit there was very little drainage passing from the lagoons, not sufficient to enter the outfall pipe, and what was draining away found access to the open ditches on the fen.

Description of the disposal of sewage from Bracebridge Asylum.—In the first days of of February, 1905, there were 876 persons resident in the asylum. The amount of sewage passing from the asylum is 30,000 to 35,000 gallons daily, an average of about 40 gallons per head.

The asylum sewage farm, which is underdrained, is situated on the slope of the hill on which the Cross Cliff Hill Water Reservoir of the Lincoln Corporation is placed. The area of the farm is some 20 acres, of which 12 acres are under cultivation and eight acres are grass land. The farm is in charge of a foreman (Richardson), and he is assisted by harmless lunatics, as a great deal of spade work is done.

The sewage, darkish grey in colour and having no offensive smell, is received in a small tank and distributed thence by carriers to the land, the cultivated portion of which is arranged in a series of terraces ; at every fifth terrace the sewage is collected and again passed through the earth. The effluent 105,000 gallons a day, a calculation made when there had been no rain for some days, is three times as great as the amount of sewage which passes from the asylum. This increase in amount is said to be partly due to springs in the sewage farm—but also, it is stated, that the Cross Cliff Hill Reservoir leaks and that the water from the Reservoir finds its way into the asylum sewer, which passes within some 15 yards of the Reservoir and at a lower level. After leaving the sewage farm, the effluent was formerly piped under the railway to an open brick tank 6 feet by 3 feet 6 inches, thence into stoneware pipes 9 inches in diameter, under the grounds of a private house to a pond of about one-third of an acre. The outfall from the pond ran over a shallow weir and after crossing, in a stoneware pipe 15 inches diameter, more private land, discharged into the River Witham near Bracebridge Bridge, some 1,400 yards above the intake of the Lincoln Waterworks. The effluent as discharged from this pipe appeared clearer than when it left the sewage farm.

The effluent from the asylum sewage farm was diverted and turned into the Bracebridge Urban District sewers on February 3rd, 1905.

The question of diverting this effluent from the River Witham has at sundry times been the subject of consideration by the three interested parties, the Lincoln Corporation, the Bracebridge Urban District Council, and the Bracebridge Asylum Visiting Committee, and towards the end of 1898 they were all in agreement. The asylum was to pay £15 per annum for the wayleave for their effluent water through the Bracebridge main sewer, and the Corporation of Lincoln, into whose sewers the Bracebridge sewage discharges, agreed to this being done, "the work being carried out under the superintendence of the City Surveyor, at the cost of the visitors of the asylum." Some two years, however, elapsed before the matter is again referred to in the official minutes. It was known that the amount of sewage entering the sewage farm was only about one-third of the effluent leaving the farm, and discussions took place as to what constituted the effluent of the sewage farm. Also it was found that to make the connexion in such a way as to exclude certain ground water would increase the cost to £145. But again in 1901 it was agreed that the effluent should be diverted to the Bracebridge Sewer. The Corporation of Lincoln, however, did not press the matter, as after consenting to receive it, the City Surveyor reported that a capital expenditure of £1,000 to £1,500 in the construction of additional bacterial filter beds would be necessitated and an additional annual charge of £145 would be involved ; moreover, the Corporation were fully aware that the treatment of their own farm effluent was not up to the required standard, and that the Branston Rural District Council had complained of the pollution of the Sincil Dyke by the Lincoln Corporation Sewage Farm. The Corporation felt that they were not in a position to deal in a satisfactory way with a daily addition of 150,000 gallons of sewage. In consequence the matter was

allowed to lie dormant, until the present epidemic of enteric fever occurred, when the effluent from the sewage farm of the asylum was, as has been stated, taken to the Lincoln sewage farm viâ the sewers of the Bracebridge Urban District Council. In view of the fact that the effluent as it leaves the farm exceeds by 70,000 gallons daily the actual amount of sewage received from the asylum it is probable the Corporation will consider whether it would not be economy in the end to construct a sewer by which the sewage from the asylum would be taken direct into the Lincoln sewers without passing it through the asylum sewage farm, for the added quantity of sewage has ultimately to be treated at the Lincoln sewage farm. This sewer, if constructed, would in any case for a considerable portion of its length, be outside the City boundary; there are certain engineering difficulties and, of course, the financial aspect to be dealt with, but these do not appear to be insurmountable.

Bracebridge Urban District: Sewerage and House Drainage, Excrement Disposal and Removal, Scavenging, Refuse Disposal.—Outside of the 446 houses in the Bracebridge Urban District, 406 drain to the system of sewers connected with those of Lincoln. These are all in the area which forms the "drainage district," and which lies nearest to Lincoln, *i.e.*, the Northern part of the District. Of these 406 houses, 128 have outside water-closets and six have inside water-closets, and the greater number of these have flushing cisterns. The remainder for the most part have the old insanitary vault privy, though there are a few box or pail closets. The obligation of emptying these vault privies devolves upon the householder, and in great part the contents are disposed of in the gardens. The portion of the district situated to the west of the main road has, in the main, only slop drainage, though a certain number of the dwellings have since the enteric fever outbreak been provided with water-closets. There is a large sewer which receives storm water and road and yard washings from a portion of the district, and this discharges to a ditch which drains to the River Witham. Refuse is disposed of to ashbins and middens, some of the latter being uncovered, and built of brick and uncemented inside, with the floors below the ground surface. The district is scavenged by contract, and the contractor disposes of the refuse on land outside the district. He attends on receiving notice from the householders.

New Boultham: Sewerage and Drainage, Excrement Disposal and Removal, Scavenging, Refuse Disposal.—There are some 177 houses in this district, and 21 have privy boxes or pails, 51 privy vaults, and the remainder outside water-closets. The houses all drain to an extension of the Lincoln sewers, and are supplied with Lincoln water. The houses are mainly fairly modern artizans dwellings. As in Lincoln the second trap on the house drain is omitted. The house drains are generally pipes 4 inches in diameter, occasionally 6 inches, and are ventilated by up shafts. The refuse is disposed of in ashbins, and there are a few middens. The district is scavenged by contract, and the refuse removed on receipt of notice from the householders.

APPENDIX 3.

Administrative Measures in view of the Fever Epidemic.

1. The Sanitary Staff.—The Sanitary Staff of the Corporation of Lincoln at the commencement of the epidemic, consisted of :—

A Medical Officer of Health.

An Inspector of Nuisances.

An Assistant-Inspector of Nuisances.

An Apprentice who assisted the Inspector of Nuisances in his work.

The Medical Officer of Health.—Charles Harrison, M.D., D.P.H., who is in general practice, was appointed Medical Officer of Health on the formation of the Sanitary Authority in 1866, at a salary of £15 per annum, increased in 1873 to £20, in 1878 to £40 and 1900 to £75 per annum. He is not provided with an office, nor with the services of a clerk.

Dr. Harrison is fully acquainted with the sanitary needs of his district and has an accurate knowledge of his duties; he has kept the sanitary needs of the City well before the Corporation. The City Council has been tardy in carrying out certain of the requirements of their Health Officer, who can, however, look back to a long record of good work well done.

Mr. Curtin, the Inspector of Nuisances, was appointed November 2nd, 1897, at a salary of £125, increased in 1900 to £150, and in 1902 to £175. He enjoyed the reputation of being an able and efficient officer. Though manifestly ill at the time of my arrival in Lincoln he accompanied me during the first day. Unfortunately he developed that night the symptoms of onset of enteric fever, and his illness terminated fatally. His loss, at this juncture, was severely felt in the City of Lincoln.

The Assistant-Inspector of Nuisances had not been many months in office, and before his appointment he had had no special training in sanitary work.

As I have stated in my report, Dr. Harrison during the early days of the epidemic was confined to his house by an attack of influenza. He was able, however, at this critical time to guide and direct the work of others; his intimate knowledge of every part of his district proved of great value.

With the Medical Officer of Health and the Inspector of Nuisances ill, it became necessary to at once form an efficient sanitary staff, with the principals trained in the duties they would have to perform. I therefore, on February 2nd, advised the representatives of the Corporation to solicit from some large provincial town the services of an Assistant Medical Officer of Health and an experienced Inspector of Nuisances from the same sanitary authority. Telephonic communication was at once established with Nottingham, and by the courtesy of the Corporation of that City, and of Dr. Boobyer, their Medical Officer of Health, Dr. Rees Jones, their Assistant Medical Officer of Health, and Mr. H. Ward, an Inspector of Nuisances, arrived and commenced work in Lincoln the following day.

There was thus no appreciable break in the continuity of administration, and such admirable tact and judgment did these officers exercise in carrying out their duties, that probably only those who were intimately associated with them in their work realized how efficiently they performed, in a city to which they were strangers, and during the height of a serious epidemic, the difficult and responsible task allotted them.

Later, Nottingham placed at the disposal of Lincoln the services of two other Inspectors of Nuisances, who assisted materially in training the temporary officers recruited for the additional work thrown on the Lincoln Sanitary Authority by the epidemic.

Bracebridge Urban and Branston Rural Districts.—Dr. Harrison is also Medical Officer of Health for both these districts; and Dr. Rees Jones was temporarily appointed Assistant Medical Officer of Health to them during Dr. Harrison's illness. Bracebridge Urban District has one, and Branston Rural two Inspectors of Nuisances, but these three officers do not devote all their time to the duties of their office as Inspectors of Nuisances.

The fact that the three districts have a Medical Offcer of Health in common rendered co-ordination of the work comparatively easy, especially, as will be seen later, both the smaller districts are so largely dependent on the sanitary equipment of the City of Lincoln.

2. Notices issued by the Sanitary Authorities.—The public were first warned of this rising epidemic by a notice, ordered to be printed and issued by the Waterworks Committee on January 19th, advising that the water be boiled before use, on account of the increased demand for water brought about by the frost causing "the water to pass through the filters "much more rapidly than should be the case"; no reference was made to enteric fever. The distribution of this notice, which was begun on January 23rd, and of which some 13,000 copies were printed, was left to the Waterworks Engineer, who signed the notice on behalf of the Waterworks Committee, and he deputed certain of his workmen for this service. The distribution of these notices was neither systematically, efficiently, nor speedily performed.

It was followed by another notice, dated January 27th, signed by the Deputy Town Clerk, and issued by the Health Committee, urging the public during the existence of the outbreak of enteric fever not to consume water or milk until the same had been thoroughly boiled. This notice was circulated in much better fashion. It was followed a few days later by another somewhat similar notice.

Following the publication of these notices, placards were posted in both the Bracebridge Urban District and in the Branston Rural Districts warning the inhabitants to boil the water, and giving directions as to dealing with the disease.

3. Isolation Hospitals and provision of Temporary Hospital Accommodation.—The Corporation has at Long Leys on the western side of, and one and a-half miles from the centre of the City, an Isolation Hospital, built on loan after an inquiry by the Local Government Board in 1903. It consists of an administration block, a scarlet fever pavilion with 14 beds, a laundry and disinfecting block, mortuary, ambulance shed, and tool house. A galvanised iron building, with accommodation for 9 beds, which formerly stood near the race course, is now erected at this hospital. Water and gas are laid on from the City mains, and the drainage passes to the City sewerage system. There is room for extension of the hospital buildings on this site.

In addition to the Isolation Hospital, the Corporation possesses an old and somewhat delapidated wooden building, arranged for 20 beds, which formerly served as their Isolation Hospital. It stands on the Race Common about a mile and a-half to the west of the City, and is composed of four wards placed two on each side of a central room. These wards communicate directly with one another, so that one infectious disease only can be treated at the same time. The hospital communicates by a covered corridor with a well-built brick structure, containing four rooms and a dispensary, and intended for the accommodation of the nursing staff. The wards are provided with stoves, and there are pail closets, placed at the ends of the buildings, and properly disconnected by a cross ventilating space; the roofs are covered with tarred felt. The hospital is only separated from the Common by an iron railing. The sewage discharges into cesspools. A caretaker and his wife reside in the hospital, with a view to keeping it ready for the isolation of small-pox patients. By the advice of Dr. Harrison, this hospital was not used for the reception of any of the enteric fever patients during the epidemic; the wisdom of this was proved, as on a case of small-pox occurring in the City during the enteric fever outbreak, it was promptly isolated in this hospital, and no further cases occurred.

There are also on this Common some sheds hastily run up a few years ago, on the occasion of a local outbreak of small-pox, for the isolation of contacts.

Neither *Bracebridge Urban* nor *Branston Rural District* possess an Isolation Hospital, and throughout the epidemic of enteric fever these districts were dependent on Lincoln for the reception and treatment in hospital of such cases of the fever whose circumstances necessitated it. Such cases were never refused by Lincoln.

The galvanized iron building, which is used as the enteric fever block at the Corporation hospital at Long Leys, was quickly filled with patients, and the scarlet fever pavilion was taken into use for the reception of cases of enteric fever, extending the accommodation available at this hospital to 23 beds, but the number of patients under treatment at one time exceeded this figure.

The Blenkin Memorial Hall in Kingsley Street, was then prepared for use as a hospital (17 beds) and was opened for the reception of patients on the 2nd of February. This was followed by the opening for the same purpose of the Newport Hall, on February 7th (10 beds), and a day or two later (February 8th) of the Vernon Street Mission Hall (17 beds); while, by the courtesy of the Officer Commanding the First Volunteer Battalion of the Lincolnshire Regiment (Colonel Ruston), the use of the drill hall of the volunteers was acquired as a hospital and fitted for the reception of nearly 100 patients. On February 9th, a ward (20 beds) in the County Hospital was also placed at the disposal of the Corporation; and on February 22nd, St. Martin's Parish Room was opened with 22 beds as a temporary hospital. These temporary hospitals were placed in charge of the medical practitioners of Lincoln.

But, by the end of the first week in February, there were some 500 cases of enteric fever in the City and its suburbs, and the hospitals as soon as opened were promptly filled. Accommodation was given to urgent cases from the Bracebridge Urban, Branston and

Welton Rural Districts. No attempt was at this time made to remove to hospital many patients of the better class, and the poorer class who were too ill to be moved were perforce left in their homes.

Much good work was done by the members of the Special Committee of the City Council, and by the officers of the Corporation, of which a full share fell to the lot of the Medical Officer of Health and the City Engineer, who, together with Miss Henrietta Bromhead, the lady superintendent of the Bromhead Institution for Nurses, Lincoln, were specially engaged in the preparation of the buildings for use as hospitals, and in arranging for their administration. So well was this work done that I heard of no complaints as to the management of these hospitals either in the treatment of the patients or in the matter of food supply, notwithstanding the serious administrative difficulties involved, as the buildings taken into use as temporary hospitals were either not fitted with kitchens at all, or with kitchens not planned for cooking large quantities of food.

To provide the necessary laundry work also taxed the ingenuity of those responsible. The bed linen, etc., after being placed in disinfectants, was taken to the laundry of the Corporation Hospital at Long Leys. This laundry, however, planned for hospital of no more than 50 beds, proved too small to deal with the vast amount of articles which needed washing from the 200 patients treated in hospitals, although it was kept working at high pressure day and night. The public laundries in Lincoln and the neighbouring large towns feared to take the Corporation washing, and the supply of bed linen and patients' body linen seemed for a brief period likely to fall short of the requirements.

4. Nursing arrangements at Hospitals.—The arrangements for nursing at the temporary hospitals and the organisation of the district nurses was carried out by Miss Henrietta Bromhead, the lady superintendent of the Bromhead Institution for Nurses, Lincoln.

In 1897, a fund of £5,000 was raised in Lincoln, a deed of Trust formed, and the money invested. The income from this fund is paid to Miss Bromhead "to be by her applied in training and maintaining Nurses, to be designated and known as "Nurses maintained by the Queen Victoria City of Lincoln Nursing Fund," and to be employed in nursing "the sick and poor inhabitants of the City." There are some 70 nurses attached to the Bromhead Nursing Institution, and during the epidemic these were fully occupied in the ordinary private and district nursing in the City. Nearly 100 extra nurses were engaged of which 12 were supplied gratuitously from the Institution, and the remainder paid for by the Corporation or through private generosity. The sleeping accommodation for the staff at the temporary hospitals was not sufficient for all the nurses engaged in the hospital work, and as a consequence some of them, together with certain of the nurses attending to the sick in their homes, were received as guests into the houses of many citizens.

5. Disinfection.—The City of Lincoln has a Defries Equifex Steam Disinfecting Apparatus which is situated at the Corporation Isolation Hospital at Long Leys. The capacity of this apparatus was taxed to its utmost during the epidemic, and it was some considerable time before the number of daily notifications of the fever fell to the number at which the bedding clothes, etc., of the sick could be disinfected without undue delay.

Articles for disinfection are taken to the hospital in a special van, and are returned in an open cart; and, as required, additional vehicles were taken into use.

Owing to the rapid development of the epidemic, certain houses were not disinfected immediately on the patient being removed to hospital, but with the advent of additional staff these arrears were dealt with; and, in a comparatively short space of time, delay in this respect disappeared.

Throughout the epidemic disinfectants free of charge, were supplied from the Corporation offices to the public, and the demand for these disinfectants was at one time very great.

Bracebridge Urban and *Branston Rural Districts* have no disinfecting apparatus. Lincoln permits these districts to use its disinfecting apparatus.

6. Ambulance.—The Corporation of Lincoln possesses a new ambulance of the brougham type, but one ambulance was found insufficient to deal with the number of cases requiring removal when the temporary hospitals were opened, and a second ambulance was borrowed for some weeks from the Metropolitan Asylums Board in London. A nurse and one of the men employed in the sanitary department accompanied the ambulance when removing patients.

7. Mortuary.—There is a public mortuary at the Lincoln Town Hall, and the Corporation also have a mortuary at the public cemetery. To this latter mortuary, the bodies of those dying in the temporary hospitals were removed pending burial.

There is no public mortuary in Bracebridge Urban nor in Branston Rural District.

8. Provision of Sanitary Paits to invaded houses.—It is the custom at Lincoln to supply a special sanitary pail to houses where a case of enteric fever occurs. These pails

are collected daily, a fresh pail being left when the first one is removed. During the enteric fever epidemic pails were supplied to the first cases of the fever, but the large number of cases notified soon exhausted the available supply of these pails. Steps were promptly taken to obtain the necessary number, but many of the first cases of fever, treated at their homes, were not provided with pails for some days. These pails, when removed from the invaded houses, were taken to the West Common where they were emptied, disinfected, washed in boiling water, and partially filled with sawdust soaked in disinfectant, before being again taken into the City. The pail contents were mixed with coke breeze and burnt in open furnaces on the Common. This work was very thoroughly done.

Similar pails were supplied in the Bracebridge Urban and Branston Rural Districts.

9. Convalescent Homes.—Preparations were made soon after the temporary hospitals were opened, to send the convalescent patients to homes to complete their restoration to health. A private house was acquired by the Lincoln Corporation for this purpose at Drinsey Nook, eight miles from Lincoln, having accommodation for 40 patients. Private generosity, through the Ladies' Committee and others, provided accommodation at Louth, Mablethorpe, Skegness, and in various houses in the country. To these homes and houses patients of the working class were sent in large numbers to complete their restoration to health.

10.—The Mayor's and other Charitable Funds.—Early in February the Mayor Alderman Wyatt, opened a Relief Fund to deal with distress among the poorer classes in consequence of invasion of their households by enteric fever. Alderman Pratt acted as secretary to this fund, which was liberally subscribed to, but no public appeal was made to the country at large. A few subscriptions were received from outside, notably, one hundred pounds from the Corporation of Maidstone, a town which suffered from a water-borne epidemic of enteric fever some years ago. A Ladies' Committee Fund was formed, and this was later amalgamated with the City Relief Fund. Miss Bromhead also received contributions for her Patients' Relief Fund, in money and in kind. Gifts of clothing, parcels of old linen, food and brandy were freely given. One large employer of labour provided food for his workmen when their wives were attacked by the disease and, when hospital accommodation was not available, a staff of nurses to nurse such cases as occurred in the houses of his workmen.

APPENDIX 4.

1. *Work of Sanitary Improvement carried out by the Corporation of Lincoln since Dr. Wheaton's visit in* 1894.

It is matter of interest to note the work of sanitary improvement carried out by the Corporation during the past ten years, since the visit of inspection made by my colleague, Dr. Wheaton, in 1894.

On a suitable site, large enough to allow of extension of the buildings, the essential parts of a well-equipped isolation hospital have been built.

A proper ambulance and a disinfecting apparatus have been supplied.

The number of vault privies, and uncovered midden privies has been materially reduced, water closets and sanitary dust bins being substituted.

Insanitary property has been dealt with, and structural defects unfitting the dwellings for habitation, have to a great extent been remedied.

Under the late Inspector of Nuisances, Mr. Curtin, nuisances were dealt with when discovered, but clearly he had no sufficient staff working with him to permit of nuisances being sought out thoroughly and systematically, and abated.

A public slaughter-house, well designed and constructed, has been built, and some old slaughter-houses—The Butchery—in the city have been closed for slaughtering.

The difficulty of sewage disposal was resolutely grappled with until the end of 1903, when unfortunately the work of erecting additional bacterial beds was discontinued.

2. *Work of Sanitary nature still requiring to be done.*

The needs of the city now are :—

Augmentation of the "personnel" in the Department of the Medical Officer of Health; and this staff should have improved office accommodation.*

Nuisances should be sought out and abated independently of complaints from inhabitants.

Defective slaughter-houses and insanitary cowsheds should be made to comply with modern requirements.

The keeping of pigs should be carefully regulated.

The byelaws, when the code is revised, should be enforced.

The provision of a refuse destructor would be a useful addition to the sanitary plant of the city.

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* Since this was written I learn that Dr. Harrison has been appointed Medical Officer of Health at an increased salary, and that his staff has been increased as follows : an Assistant Medical Officer of Health, who devotes the whole of his time to the duties of his office, two trained Inspectors of Nuisances ; the former Assistant Inspector of Nuisances is to be a clerk until he qualifies as an Inspector of Nuisances.

ADDENDUM I.

Reports by Clinical Research Association on Lincoln Water.

(Copy.)

THE CLINICAL RESEARCH ASSOCIATION, LIMITED.

1, Southwark Street,
London Bridge, S.E.,
17th January, 1905.

To Dr. Harrison,

The specimen of water marked , received here on 7th January, 1905, has been chemically and bacteriologically examined, and I have been instructed to forward the following analysis and report thereon :—

Analysis.

—	Grains per gallon.
Total solids (dried at 120° C.)	28·00
Combined chlorine	2·60
Expressed as NaCl	4·29
Nitrogen as nitrates	·26
Nitrites	Nil
Saline ammonia	0·0008
Albuminoid ammonia	0·0107
Oxygen absorbed in four hours at 27° C.	0·094
Total hardness	13°·4
Lead or copper	Nil

This water contains much unoxidised matter, as shown by the high figures for albuminoid ammonia and oxygen absorbed. From a chemical point of view it is not fit for drinking.

Bacteriological examination.—The number of organisms which produce colonies on gelatine plates incubated at 20° C., is 149 per cubic centimetre of the sample.

The bacillus coli communis is found to be present in quantities of five cubic centimetres and upwards, while coli-form organisms which do not give all the bacillus coli tests are present in as small a quantity as 0·2 cubic centimetre. The bacillus typhi abdominalis is not detected.

The total number of organisms in this water is not excessive, but the presence of intestinal bacteria must be regarded as evidence strongly suggestive of pollution with sewage or fæcal matter.

C. H. Wells,
Secretary.

Fee, 63*s*.

(Copy.)

THE CLINICAL RESEARCH ASSOCIATION, LIMITED.

147, 148/2.

1, Southwark Street,
London Bridge, S.E.,
14th February, 1905.

To Dr. HARRISON,

The specimen of water, marked X, Tap Water in Fishmarket, received here on 3rd February, 1905, has been chemically and bacteriologically examined, and I have been instructed to forward the following analysis and report thereon :—

CHEMICAL ANALYSIS.

——	Grains per Gallon.
Total solids (dried at 120° C.)	26·60
Combined chlorine	2·55
Expressed as NaCl	4·21
Nitrogen as nitrates	0·27
Nitrites	Nil
Saline ammonia	0·0012
Albuminoid ammonia	0·0088
Oxygen absorbed in four hours at 27° C.	0·089
Total hardness	14°·0
Lead or copper	Nil

This water contains a suspiciously high proportion of unoxidised organic matter, as shown by the rather high figures for albuminoid ammonia and oxygen absorbed. A little saline ammonia and a trifling proportion of nitrates are also present.

The water must be considered as of very doubtful organic purity as judged by chemical analysis, and certainly not a safe one for drinking.

Provisional Bacteriological Report.—The number of organisms which produce colonies on gelatine plates incubated for 72 hours at 20° C., is 248 per cubic centimetre of the water, and about half the colonies are of the coli-form type.

Quantities of the water varying from 0·2 to 35 cubic centimetres have been investigated for the identification of the bacillus coli communis, and with the result that many varieties of bacilli belonging to the coli group have been isolated from 0·2 cubic centimetre of the sample ; so far, however, not one is found to show all the cultural features of the typical bacilli coli communis, but we have little doubt that there are intestinal organisms present, and the isolation of the typical colon bacillus will probably be accomplished in the course of a few days.

CHAS. H. WELLS,
Secretary.

(Copy.)

THE CLINICAL RESEARCH ASSOCIATION, LIMITED.

151, 152/2.

1, Southwark Street,
London Bridge, S.E.,
14th February, 1905.

To Dr. HARRISON,

The specimen of water, marked Z, Pure Water Tank, received here on 3rd February, 1905, has been chemically and bacteriologically examined, and I have been instructed to forward the following analysis and report thereon :—

CHEMICAL ANALYSIS.

——	Grains per gallon.
Total solids (dried at 120° C.)	26·95
Combined chlorine	2·60
Expressed as NaCl	4·29
Nitrogen as nitrates...	0·26
Nitrites	Nil
Saline ammonia	0·0018
Albuminoid ammonia	0·0100
Oxygen absorbed in 4 hours at 27° C.	0·093
Total hardness	14°·4
Lead or copper	Nil

This water contains much unoxidised organic matter; the figures, the albuminoid ammonia and oxygen absorbed, are both high.

Saline ammonia is present, as also a trifling proportion of nitrates. From a chemical point of view this water must be considered as unfit for drinking.

Provisional Bacteriological Report.—The number of organisms which produce colonies on gelatine plates incubated for 72 hours at 20° C., is 553 per cubic centimetre of the water, and at least half the colonies are seen to be of the coli-form type.

For the detection of intestinal organisms, quantities of the water, varying from 0·2 cubic centimetre to a total of 35 cubic centimetres, have been heated by a process almost identical with that employed by Pakes for the isolation of the bacillus coli communis. So far it has been found that coli-form organisms are present in 0·2 cubic centimetre of the water, but vary in their characters to a most unusual extent, and while the great majority of the bacilli which have been isolated from the water show most of the cultural features of the colon bacillus, not one has been found up to the present which gives all the typical tests. We have met with this difficulty before in the case of waters known to be much polluted, and from our experience of such samples we have little doubt that the typical bacillus coli communis is present in the water.

The investigation is being proceeded with, and a further report will be sent as soon as possible.

CHAS. H. WELLS,
Secretary.

(Copy.)

THE CLINICAL RESEARCH ASSOCIATION, LIMITED.

149, 150/2

1, Southwark Street,
London Bridge, S.E.,
14th February, 1905.

To Dr. HARRISON,

The specimen of water, marked Y, Water from Tap at Clark's, Salter Gate, received here on 3rd February, 1905, has been chemically and bacteriologically examined, and I have been instructed to forward the following analysis and report thereon :—

CHEMICAL ANALYSIS.

——	Grains per Gallon.
Total solids (dried at 120° C.)	26·60
Combined chlorine	2·55
Expressed as NaCl	4·21
Nitrogen as nitrates...	0·27
Nitrites	Nil
Saline ammonia	0·0012
Albuminoid ammonia	0·0090
Oxygen absorbed in four hours at 27° C.	0·089
Total hardness	14·°0
Lead or copper	Nil

The water is almost absolutely identical in character with No. 148/2 (marked X), and the remarks on that sample apply to this one also.

It is not a safe water for drinking.

Provisional Bacteriological Report.—The number of organisms which produce colonies on gelatine plates incubated for 72 hours at 20° C., is 292 per cubic centimetre of the water, and at least half of the colonies are of the coli-form type.

Quantities of the water, varying from 0·2 to 35 cubic centimetres, are being investigated for the detection of the bacillus coli communis, and organisms belonging to the coli group are found to be present in the smallest quantity taken (viz., 0·2 cubic centimetre of the water). The organisms show great variation in their characters, and so far not one is seen to be absolutely typical. There is practically no doubt, however, that intestinal organisms are present, and we hope to isolate the typical bacillus coli communis in the course of a few days.

CHAS. H. WELLS,
Secretary.

(Copy.)

THE CLINICAL RESEARCH ASSOCIATION, LIMITED.

147/2.

1, Southwark Street,
London Bridge, S.E.,
20th February, 1905.

LABORATORY REPORT.

To DR. HARRISON,

The specimen of water, marked X, Tap Water in Fishmarket, received here on 3rd February, 1905, has been duly examined, and I have been instructed to forward the following report thereon :—

Further Report.—As a result of the further investigation of this water a bacillus having the microscopic and cultural characters of the typical bacillus coli communis has now been isolated from one cubic centimetre of the sample.

We are of opinion that the bacteriological examination proves the presence of numerous intestinal organisms, and that when judged by the condition of the sample, there is distinct evidence that the water is unfit for drinking.

C. H. WELLS,
Secretary of the Association.

(Copy.)

THE CLINICAL RESEARCH ASSOCIATION, LIMITED.

151/2.

1, Southwark Street,
London Bridge, S.E.,
20th February, 1905.

LABORATORY REPORT.

To DR. HARRISON,

The specimen, marked Z, Pure Water Tank at Waterworks, received here on 3rd February, 1905, has been duly examined, and I have been instructed to forward the following report thereon :—

Further Report.—As already stated in the preliminary report (151/2) this sample of water has been found to contain an unusually large number of coli-form organisms which vary greatly in their cultural features ; and as a result of further investigation we have now isolated—from one cubic centimetre of the sample—an organism which gives all the usual tests for the typical bacillus coli communis.

We are of opinion that the sample contains numerous intestinal organisms, pointing to serious pollution with sewage or fæcal matters, and that in its present condition it is quite unfit for drinking.

C. H. WELLS,
Secretary of the Association.

(Copy.)

THE CLINICAL RESEARCH ASSOCIATION, LIMITED.

149/2.

1, Southwark Street,
London Bridge, S.E.,
20th February, 1905.

LABORATORY REPORT.

To DR. HARRISON,

The specimen of water, marked Y, Water from Tap at Clark's, Salter Gate, received here on 3rd February, 1905, has been duly examined, and I have been instructed to forward the following report thereon.

Further Report.—In addition to the numerous coli-form organisms already found in this water we have now succeeded in isolating from one cubic centimetre of the sample a bacillus having the characteristic microscopic and cultural features of the typical bacillus coli communis.

As a result of our investigation we are of opinion that there is evidence of pollution with sewage or fæcal matter, and that, judging from the condition of the sample, the water is unsafe for drinking.

C. H. WELLS,
Secretary of the Association.

ADDENDUM II.

Extracts from a Report by Dr. Klein on the Bacteriological Examination of Lincoln Water.

St. Bartholomew's Hospital, E.C.,
20th February, 1905.

The Medical Officer of the Local Government Board.

On February 1st I received three samples of water, labelled as follows :—

(1) Water from pure water tank, taken 1st February, 1905.

(2) Pike Drain water, 1st February, 1905.

(3) Water from Catchwater *inlet*, indirectly from River Witham, taken 1st February, 1905.

These three samples will in this report be described as sample 1, sample 2, and sample 3, respectively.

The total amount of water of sample 1 was about 350 cc. ; clear.

The total amount of water of sample 2 was about 1,000 cc. ; turbid.

The total amount of water of sample 3 was about 750 cc. ; turbid.

These three samples were subjected to analyses (*a*) with a view of general orientation and (*b*) with a view to detect specific pollution, if any.

(*a*) For general orientation :—

Sample 1 contained 64 bacteria per 1 cc.

„ „ B. coli communis in 1 cc., not in $\frac{1}{10}$ cc.

„ „ no spores of B. enteritidis sporogenes in 100 cc.

Sample 2 contained 2,500 bacteria per 1 cc.

„ „ B. coli communis 1 in cc., not in $\frac{1}{10}$ cc.

„ „ spores of B. enteritidis sporogenes in 100 cc., not in 10 cc.

Sample 3 contained 3,500 bacteria per 1 cc.

„ „ B. coli communis in $\frac{1}{10}$ cc. (some other acid-producing microbe in $\frac{1}{100}$ cc.).

„ „ spores of B. enteritidis sporogenes in 10 cc., not in 1 cc.

(*b*) For specific pollution :—

Sample 1.—As mentioned above, of sample 1 there were altogether available about 350 cc. only. Of this amount about 120 cc. were used for general orientation. The remainder, about 220 cc., was subjected in two lots to the centrifuge, and the resulting sediment was used for four large plates containing Drigalski-Conradi medium.

. . . . . .

Of the four Drigalski-Conradi plates prepared with the sediment of sample 1, two had no bluish colonies, the third had five blue colonies of bacilli, and the fourth plate had one blue colony of diplococci. The five blue colonies of bacilli presented, however, no characters in any way suggestive of B. typhosus or B. Gaertner : so that of sample 1, *i.e.*, about 220 c.c., no microbe of this type was obtained.

Sample 2.—Of this sample about 750 cc. were passed through a Pasteur filter, and with the filter-brushings four large Drigalski-Conradi plates were made. In these plates a number of blue colonies developed. Only three of them, however, showed characters presumptive of B. typhosus. Of these three colonies gelatine subcultures were made ; with the result that one of the three became at once eliminated on account of its liquefying the gelatine. Of the two remaining colonies, which in respect of aspect and constitution in the Drigalski-Conradi plates resembled the B. typhosus, subculture by gelatine streak gave the characters of B. typhosus ; viz., translucent, dry growth with irregular filmy spreading margin. The micro-organisms constituting the growths were motile bacilli, showing more or less retarded agglutination with the laboratory rabbit serum. These colonies, to be referred to as colony 1 and colony 2 (of sample 2), were then subjected to further tests ; with the result that colony 1 turned out to be identical with B. Gaertner, colony 2 with B. typhosus. There were, however, certain small differences in both cases.

Colony 1, the characters of which are compared and summarised with B. Gaertner in Table A, showed on the surface of gelatine an expansion, which, after several days' growth, was somewhat less transparent and less dry looking than the growth of the laboratory B. Gaertner. Further, although it clumped well and decisively with the blood serum of a Gaertner rabbit—which had been prepared by intravenous injection with the laboratory B. Gaertner—its bouillon emulsion *did not* clump so promptly as that of the laboratory B. Gaertner, *i.e.*, as the microbe used for the injection of the Gaertner rabbit.

Colony 2.—This microbe showed slower agglutination with the laboratory typhoid-rabbit's blood serum than the laboratory B. typhosus; moreover, the agglutination was not complete in an hour, whereas the laboratory B. typhosus was clumped in complete manner in five minutes.

But in all other respects *colony* 1 was identical with B. Gaertner, and *colony* 2 with B. typhosus—as is shown in Table A appended to this report.

Sample 3.—Of this sample the whole of the quantity not used for test in general orientation was passed through a Pasteur filter. The filter-brushing thus obtained was used for four large Drigalski-Conradi plates. As a result, amongst a large number of blue colonies that appeared in these plates, only six could be considered as a result of inspection with a glass and of microscopic examination in the hanging drop, as complying with the preliminary tests of B. typhosus. By subculture on gelatine surface three of these six colonies were eliminated; they proved liquefiers. The remaining three colonies, Nos. 1, 2, and 3, respectively, complied on gelatine subculture with the requirements of B. typhosus. They were therefore subjected to all the further tests, with results which are summarised in Table A. From this it will be seen that while colony 2 reacted positively for B. typhosus in every respect, colonies 1 and 3 failed in one or the other particulars. Colony 1 gave no indol in broth culture for 10 days, though after 11 days it gave just a trace of indol reaction; and, further, Proskauer and Capaldi medium I. which had been inoculated with it, showed, after 48 hours' incubation at 37° C., a trace of changing into red, indicating a tendency to produce acid. Colony 3 likewise gave no indol reaction in broth for 10 days, though after 12 days' incubation there was perhaps a trace of indol. Moreover, it produced slight redness in Proskauer and Capaldi I. after 48 hours' incubation at 37° C. The litmus milk culture of this microbe was inspected daily, and the gradual reddening (acid production) was noticed, the milk remaining, meanwhile, fluid. After 12 days, however, it was found clotted.

Both these colonies (1 and 3) gave distinct agglutination, only agglutination was slower than with the laboratory B. typhosus, or with colony 2 of the same sample.

The conclusion which I draw from these observations I have summarised in Table B.

On February 4th, I received, Sample 4, a bottle of a thick brownish turbid fluid representing "a filter-brushing from two Pasteur-Chamberland filters in use in Lincoln, which had not been cleaned for three months.":

Sample 4.

A tenth of a cc. of the turbid fluid was used for each of four Drigalski-Conradi plates, with the result that no colonies (red or blue) appeared in them after incubation at 37° C. for several days; they remained, indeed, free of any such colonies after 10 days. Seeing that after 24 hours' incubation the plates when examined carefully under a magnifying glass, were free of colonies, it was clear that in $\frac{1}{10}$ cc. of the turbid fluid there were no living microbes belonging to the coli-typhoid group. Further cultures were therefore made with the fluid—which had been kept meanwhile in the cool chamber—in the following manner:—

(*a*) Two phenol-broth tubes and two tubes containing MacConkey-fluid received each $\frac{1}{2}$ cc. of the turbid fluid direct;

(*b*) 100 cc. of the turbid fluid were subjected to the centrifuge, and, with the sediment, two large Drigalski-Conradi plates were inoculated. The result was this:—

(*a*) Both MacConkey tubes remained unaltered after incubation for 48 hours; both phenol-broth tubes were turbid. From each of these phenol-broths a Drigalski-Conradi plate was made; but no colonies appeared in them. Proof was thus afforded that the turbidity of the phenol-broth tubes had not been caused by microbes belonging to the coli-typhoid group, and tended to confirmation of the negative results with the two MacConkey tubes.

(*b*) The two Drigalski-Conradi plates made with the sediment of 100 cc. centrifuged filter-brushing, developed no colonies of the coli-typhoid group, but each plate showed after several days' incubation at 37° C. several dozen minute dot-like colonies of cocci.

The result of analysis, therefore, of sample No. 4, showed that even considerable amounts of the turbid fluid contained no living microbes of the coli-typhoid group.

Sample 5.

On February 11th I received a bottle of "Muddy water, being sediment from the pure water tank which receives the Lincoln water after filtration through the sand filters." This sample was practically fluid mud, and will be referred to as "mud of tank." The

bottle, having been well shaken up, was allowed to stand in the cool chamber for an hour: the turbid fluid—about 100 cc.—was then siphoned off from the top of the sediment, and subjected to the centrifuge. With the centrifuged deposit the following cultures were made :—

(*a*) Four MacConkey tubes, and

(*b*) Four large Drigalski-Conradi plates.

After incubation of (*a*) for 24 hours, one only of the four MacConkey tubes showed redness without gas ; the other three showed redness with copious gas. Drigalski plates of these three tubes brought forth, amongst a large number of neutral colonies, numerous colonies of B. coli, but no blue colonies ; a Drigalski plate of the fourth tube showed, amongst numerous neutral or pink colonies, very few bluish ones. But none of these blue colonies complied with the requirements of B. typhosus. Subcultures were, however, made of them in gelatine streak and gelatine shake ; but they could be soon discarded as not being either B. typhosus or B. Gaertner.

The four Drigalski-Conradi plates (*b*) made directly with the centrifuged sediment brought forth large numbers of blue colonies. Of these the great majority could at once tbe rejected ; they were flat and coarsely granular or rapidly spreading films ; or were too uniformly raised without granulations ; or when examined in the hanging drop did not show any tendency to emulsify. Eight blue colonies, however, which complied with the preliminary tests for B. typhosus were selected for gelatine subculture. After 24 hours seven of these could be eliminated on account of their liquefying the gelatine : so that one only remained. This was then subjected to the further tests, with the results summarised in Table B. From this table it will be seen that the particular colony complied in all respects with the tests of B. typhosus, except as regards the following :— In Proskauer and Capaldi medium II. acid production after 48 hours' incubation was doubtful ; litmus milk after four days' incubation at 37° C. did not exhibit pronounced red colour, it therefore failed to yield the distinct acid production which is characteristic of B. typhosus ; and, further, agglutination with the typhoid serum of the laboratory, though distinct within the hour, was slow.

I therefore consider this microbe possibly but not probably a variety of B. typhosus.

E. KLEIN.

TABLE A.—Showing the general characters of typical B. coli communis, of B. Gaertner and of B. typhosus, as also those of the special microbes isolated from the Lincoln samples.

Source of Microbe.	Morphology.*	Drigalski Plates.	Gelatine Streak.†	Neutral Red Broth.	Phenol Broth.	Indol Formation.	Litmus milk.	Proskauer and Capaldi.		MacConkey Fluid.	Peptone, Litmus Lactose.	Agglutination with Typhoid Serum 1 : 20.
								Medium I.	Medium II.			
B. coli com. (Sewage) ...	Short rods, slightly motile.	Red colonies with red halo.	Rapidly spreading, dry, fairly opaque.	Greenish fluorescent.	Uniform turbidity in 24–48 hours.	Positive within a week.	Red, clotted within a week.	Acid	Alkaline	Red, copious gas.	Red, copious gas.	Negative within the hour.
B Gaertner (Laboratory)...	Short cylindrical, very motile.	Small blue colonies, raised in centre, filmy in margin.	Translucent, dry, spreading band.	,,	,, ,,	,, ,,	Blue, fluid	,,	,,	Red, gas	Negative	Slight and retarded.
Pikedrain Colony 1 ...	,,	,, ,,	Translucent, dry, spreading band, less translucent later.	,,	,, ,,	,, ,,	,, ,,	,,	,	,, ,,	,	,, ,,
B. typhosus (Laboratory)...	Cylindrical, very motile.	Blue colonies, finely granular, raised in centre, filmy in margin.	Translucent, dry, filmy margin.	Negative, cherry coloured.	,, ,,	Negative	Red, fluid	Negative	Acid	Red, no gas	Negative, bleached.	Instantaneous.
Pikedrain, Colony 2 ...	Short cylindrical, very motile.	,, ,,	,,	,, ,,	,, ,,	,, ,,	,, ,,	,,	,,	,, ,,	Negative	Distinct, but slower.
Catchwater inlet, Colony 1	,, ,,	,, ,,	,, ,,	,, ,,	,, ,,	Trace of indol after 11 days.	,, ,,	Acid (?)	,,	,, ,,	,,	,, ,,
Catchwater inlet, Colony 2	,, ,,	,, ,,	,, ,	,, ,,	,, ,	Negative	,, ,,	Negative	,,	,, ,,	Negative, bleached.	Distinct, prompt.
Catchwater inlet, Colony 3	,, ,,	,, ,,	,, ,,	,, ,,	,, ,,	Trace of indol after 12 days.	Red, clotted after 12 days.	Acid (?)	,,	,, ,,	Negative	Distinct, slow.
Mud of tank	,, ,,	,, ,,	,, ,,	,, ,,	,, ,,	Negative after 8 days.	Neutral, fluid after 8 days.	Negative	Acid (?)	,, ,,	,,	,, ,,

* All microbic species here tabulated have the common character of (*a*) not liquefying gelatine, (*b*) of being gram negative in staining.

† Gelatine shake cultures of all tabulated microbes show oolonies all through the medium, those of B. coli communis show in addition numerous gas bubbles, those of B. Gaertner and Gaertner-like microbes show few gas bubbles, and all the others are without any gas bubbles.

TABLE B.—Showing probable position of the special microbes as compared with our laboratory B. Gaertner and B. typhosus.

Derivation.	Character.	Conclusion.
Pikedrain, Colony 1	Same as B. Gaertner, except less translucent in gelatine streak in later stages.	Most probably B. Gaertner.
Pikedrain, Colony 2	Same as B. typhosus, except agglutination, with our typhoid serum slower.	Probably B. typhosus.
Catchwater inlet, Colony 1 ...	Same as B. typhosus, except doubtful in Proskauer Capaldi I., forms trace of indol after 11 days.	Possibly B. typhosus.
Catchwater inlet, Colony 2 ...	In all essential respects same as B. typhosus.	Most probably B. typhosus.
Catchwater inlet, Colony 3 ...	Same as B. typhosus, except doubtful Proskauer Capaldi I., forms trace of indol after 12 days, clots litmus milk in 12 days.	Possibly, but not probably, B. typhosus.
Mud of tank	Same as B. typhosus, except no definite acid production in 4 days in litmus milk, and no distinct acidity in Proskauer Capaldi II.	Possibly, but not probably, B. typhosus.

ADDENDUM III.

Reports by Messrs. Houston and McGowan to the Lincoln Corporation on the Lincoln Water.

Lincoln,
13th February, 1905.

To the Corporation of Lincoln.

Gentlemen,

We have the honour to submit to you the following preliminary statement on the work which you have entrusted to us.

On the evenings of February 11th and 12th the Crosscliffe and Westgate Reservoir waters were treated with a view to their purification.

Further, since the morning of February 11th, the water at the works and the sand in the filter beds have been continuously treated, with the same object. There is every reason to believe that this treatment has been successful.

We would wish, however, to point out that, so long as the source of the water supply remains under suspicion it will be necessary to continue the treatment in a modified form.

It must of course be understood that the above treatment of the water cannot help those who have unfortunately already contracted typhoid fever, although they have not yet developed its symptoms. Nor can it prevent the occurrence of secondary cases of infection.

We have been greatly assisted in our work by the Corporation Water Engineer, Mr. Teague, who has spared neither time nor trouble in placing every facility at our disposal.

We expect to leave Lincoln within the next few days, but before doing so we shall have made the necessary arrangements for continuing the sterilisation process in a modified form.

This could be carried out without much difficulty and at a moderate cost. We are of opinion that it should be certainly done.

We have the honour to remain, Gentlemen,
Your obedient Servants,

A. C. Houston.
George McGowan.

Preliminary Report on Eight Samples of Lincoln Water.

Westgate Reservoir Water.

Samples collected :—

February 13th (6 a.m.)
„ 14th (5.50 p.m.)
„ 15th (6–7 a.m.)

Crosscliffe Reservoir Water.

Samples collected :—

February 12th (6 a.m.)
„ 12th (5.15 p.m.)
„ 13th (6 a.m.)
„ 13th (6 p.m.)
„ 14th (6 a.m.)

Remarks.—None of the foregoing samples contained B. coli in 100 cubic centimetres of water. As B. coli is a more hardy microbe than B. typhosus the results indicate that the treatment of the water in the reservoir has been successful.

A. C. Houston, M.D., D.Sc.

18th February, 1905.

To the Mayor and Corporation of Lincoln.

Gentlemen,

The treatment of the water and of the sand filters at the waterworks with a solution of sodium hypochlorite was commenced on Saturday, 11th February, and on the evenings of 11th and 12th February the treatment was begun at the Crosscliffe and Westgate Reservoirs, and have been continued there at suitable intervals.

As regards the reservoirs, this was, comparatively speaking, a simple task, and the result was found to be quite satisfactory. All non-sporing forms of intestinal microbes were destroyed, and therefore, by inference, the typhoid bacillus, if it was present in the water.

In respect of the filter beds, much greater difficulties had to be met. These necessitated the use at first of a relatively stronger solution of hypochlorite, continued over a longer period, and the dose of the sterilizing agent had to be varied according to the results of our analysis. We have now reason to believe that this treatment has been successful, and we hope shortly to have further confirmatory evidence of this. We base our belief of the innocuous character of the water now sent into consumption on the facts that : (1) In all the ten analyses of the reservoir waters, after treatment, no B. coli have been found in as much as 100 cubic centimetres of the water ; (2) a similar result has been obtained in our later analyses of the water passing into consumption from the waterworks. The bacillus coli which has been present in the water before treatment and subsequent filtration, is a more hardy microbe than the typhoid bacillus. Its destruction in such a water therefore affords the strongest grounds for believing that the typhoid bacillus, if present, has likewise perished.

The purified water has, no doubt, a slight taste and smell, but, with the lesser quantity of hypochlorite now necessary, this has greatly diminished. In our opinion there is every reason to suppose that even a larger quantity of hypochlorite than that at present in use is perfectly harmless, and, *a fortiori*, the same may be said of the minute trace of it or of its products which may be left in the treated water. Comparative, if not absolute, immunity from danger to health, conferred by the sterilisation of a water, even if the sterilised water possesses in consequence a slightly unpleasant taste and smell, is to be preferred to the grave risk attending the use of a palatable but impure water.

Until a new and satisfactory supply of water has been obtained we are of opinion that the above treatment of the water should be continued, under constant supervision, and that it should be controlled by periodical analyses.

To conclude :—We believe that the treatment has been successful, and, for the reason, already given, that the water may now be reasonably regarded as safe for domestic uses. But although the results of our analyses seem to show that boiling the water is no longer necessary, we do not at this stage feel justified in saying that this additional precaution (boiling) should be discontinued.

We are, Gentlemen,
Your obedient Servants,

A. C. Houston.
George McGowan.

Lincoln,
25th February, 1905.

To the Mayor and Corporation of Lincoln.

Gentlemen,

In our report to you dated 25th February, 1905, we stated that we hoped shortly to have further confirmatory evidence of the successful treatment of the water. We now beg to make the following report on the bacteriological examination of further examples of water as follows :—

(*a*) Sample of water from rising main at waterworks. Collected 10.10 a.m., 4th March, 1905. This sample represents the water leaving the waterworks and passing into consumption.

(*b*) Sample of water from Crosscliffe Reservoir. Collected 6.15 p.m., 4th March, 1905, seven days after the last treatment of the water in the reservoir.

(*c*) Sample of water from Westgate Reservoir. Collected 5.45 p.m., 5th March, 1905, four days after the last treatment of the water in this reservoir.

None of the three samples (*a*, *b*, *c*) contained B. coli in 100 cubic centimetres of the water.

We regard these results as highly satisfactory. They afford confirmatory evidence of the innocuous character of the water now sent into consumption, and they show that the treatment of the water continues to be successful.

You will of course understand that this treatment is being continued, and we propose to furnish you with further reports from time to time.

We are, Gentlemen,

Your obedient Servants,

A. C. Houston.
George McGowan.

8th March, 1905.

To the Mayor and Corporation of Lincoln.

Gentlemen,

In accordance with your instructions we have examined a large number of samples of water collected between 7th March and 18th March from main taps in different parts of the area supplied with Lincoln water.

The first forty samples, all collected from separate taps, and of which the analysis has been completed, have yielded results as follows :—

No B. coli in 100 cubic centimetres of water. Thirty samples (75 per cent.).

B. coli present in 100 cubic centimetres ; absent in 10 cubic centimetres of water. Seven samples (17·5 per cent.).

B. coli present in 10 cubic centimetres ; absent in 1 cubic centimetre of water. Three samples (7·5 per cent.).

We may add that, excluding the raw unfiltered waters and a single sample of treated filtered water, we have never found B. coli in 1 cubic centimetre of any sample of Lincoln treated filtered water, whether collected at the works or from the reservoirs or water mains.

We consider these results so satisfactory that we feel justified in gradually reducing the dose of sodium hypochlorite.

In order to satisfy ourselves that any objectionable tastes and smell of the treated water is not serious, we drink the water (unboiled) daily.

A faint mawkish taste and smell still presists in the water, but we think that this will become less apparent with the diminished dose of sodium hypochlorite now in use.

We are, Gentlemen,

Your obedient Servants,

A. C. Houston.
George McGowan.

24th March, 1905.

Report of Messrs. Houston and McGowen on their Treatment of the Water.

To the Mayor and Corporation of Lincoln.

Gentlemen,

Two months having elapsed since the treatment of the Lincoln water was first commenced, we propose to report very briefly on the results obtained.

As far as possible we shall try to avoid the use of technical language, so as to present our facts in a simple form.

It must be explained at the outset that, owing to the enormous difficulties attending the isolation of the typhoid bacillus, failure to discover its presence in a water affords no proof of its real absence. Fortunately, however, a sewage-polluted water, specifically contaminated with the virus (poison) of enteric fever, contains a normal inhabitant of the intestine (B. coli) in far greater number than it does the pathogenic typhoid bacillus. Moreover, B. coli is a more hardy microbe than the typhoid bacillus. It follows, therefore, that if each of the microbes capable of causing typhoid fever (B. typhosus) is always accompanied by a large number of comparatively robust, although harmless, individuals

(B. coli), proof of the destruction of the latter affords convincing evidence of the death of the former. Consequently, we have based our belief in the innocuous character of the water passing into consumption upon the destruction of B. coli, which is always present in the raw waters ; and we may add that we have not been content with affording proof of its absence from one cubic centimetre or even 10 cubic centimetres, but have always submitted as much as 100 cubic centimetres of water to cultural tests. It is apparent, in the light of the foregoing statements, that the absence of B. coli from 100 cubic centimetres of water affords the most convincing evidence of the absence of the typhoid bacillus.

Indeed, the absence of B. coli from 10 cubic centimetres of water may perhaps be considered sufficient proof of its wholesomeness. Many bacteriologists do not condemn a water unless it contains B. coli in one cubic centimetre.

In what follows we deal with a period of two months, namely, from February 11th to April 11th, 1905 :—

Treatment of the Raw Waters at the Works.

Having regard to our experience of the germicidal action of sodium hypochlorite and to the proportions which we have thought fit to use at the works, we doubt whether any typhoid bacilli, if present in the raw waters, could reasonably be considered to have escaped destruction from February 11th to the time of writing this report.

[On February 24th the treatment was interrupted for about three hours owing to an accident to one of the pumps. Without entering into technical details, we may say that, as soon as we were informed of the accident, we took immediate and, as we believe, successful steps to prevent any ill effects which might conceivably have arisen from this.]

As regards the destruction of any typhoid bacilli, which previous to the treatment may have been present in the deeper layers of the sand filters, or in the water mains, we cannot absolutely fix a date ; but, as an extra precaution upon this point, between February 18th and 21st we treated each filter bed in turn with a strong dose of sodium hypochlorite, allowed the germicide to permeate the whole bed, and then closed the outlet valve. After a suitable interval the valve was opened, but so slightly that when the out-flowing water from the bed mixed with the rest of the filtered water from the other beds, the probability of the mixed water passing into consumption was not affected to any material extent.

To conclude, we think that if any typhoid bacilli entered with the raw water after February 11th they could not have escaped our treatment ; and, further, that if any were present in the water system subsequent to that date they could not at the outside have survived beyond February 22nd, when the sectional treatment of the filter beds was completed.

In this connection it may be noted that some exhaustive tests quite recently made in America seem to show that the typhoid bacillus cannot live for more than a few days in water.

Without entering into unnecessary detail, the following facts may serve to illustrate the success (bacteriologically) of the treatment :—

Thirty-three samples of the water, after treatment and filtration, collected between February 12th and April 12th from a main tap at the waterworks, yielded results as follows :—

9 per cent. of the samples contained B. coli in 10 cubic centimetres of water ;

24 per cent. of the samples contained B. coli in 100 cubic centimetres of water ;

67 per cent. of the samples contained no B. coli in 100 cubic centimetres of water.

Over 100 samples collected between February 23rd and April 12th from numerous main taps within the area of water supply, yielded results as follows :—

5 per cent. of the samples contained B. coli in 10 cubic centimetres of water ;

17 per cent. of the samples contained B. coli in 100 cubic centimetres ;

79 per cent. of the samples contained no B. coli in 100 cubic centimetres of water.

These results were obtained notwithstanding the absence of impounding reservoirs. If the raw water had been stored before filtration our task would have been much easier, and the dose of germicidal agent might have been reduced to about one-fifth or one-tenth of what was actually employed.

From a chemical point of view the treated water is probably slightly less pure organically than was the filtered water previous to the treatment with chloros. The latter substance appears to exert a slight solvent action upon the organic matter in the water and in the filter beds (just as it does upon the organic matter of a soil) ; but, taken in conjunction with the remarkable destruction of intestinal microbes which it effects, this circumstance is of small moment. There is no appreciable change in the water, either as regards chemical composition in general, total solids, chlorine (free or combined), or hardness.

The substance which we used for sterilization purposes gives with certain tests a well-marked colour re-action, even when diluted with one million parts of water. No comparable re-action has ever appeared in the treated water after filtration, partly because of the small dose of germicide employed, and partly because the latter was itself destroyed in killing the bacteria and oxidizing the organic matter of the water.

The minute quantity of "spent" compounds, resulting from the treatment, imparts to the treated water an appreciable taste and smell, so delicate are those two senses. But we are confident that not one part of the germicide itself in a million of water has ever reached the consumer. The taste and smell, just alluded to, no doubt constitute a slight drawback, but it seems hardly reasonable to attach any weight to this, in comparison with the supply of a water which is bacteriologically pure. That such minute traces of sodium hypochlorite, or of the compounds arising from its action upon the organic matter of the water, could prove injurious, either to human beings or the lower animals or to vegetation, is hardly conceivable.

Treatment of the water in the service reservoirs.

The water in Cross Cliffe reservoir was first treated on the evening of February 11th, and that in Westgate reservoir on the evening of February 12th. Since then the treatment has been continued from time to time, but, generally speaking, we have gradually diminished the dose and lengthened the interval between each two successive treatments.

That the treatment from the outset has been most successful is shown by the following figures :—

Samples of water were collected from the Westgate reservoir on February 13th, 14th, 15th and 19th ; March 5th, 8th, 12th, 15th, 19th and 26th ; and April 2nd, 5th and 12th.

30 per cent. of the samples contained B. coli in 100, but not in 10 cubic centimetres of water.

70 per cent. of the samples contained no B. coli in 100 cubic centimetres of water.

Samples of water were collected from the Cross Cliffe reservoir on February 12th (two samples), 13th (two samples), 14th and 20th ; March 4th, 8th, 16th, 18th and 25th ; and April 1st, 5th and 12th.

100 per cent. of the samples contained no B. coli in 100 cubic centimetres of water.

To those who are not familiar with the somewhat unusual mode of water distribution in vogue at Lincoln it may be mentioned that during the day the consumer draws more water from the rising mains than the pumps can supply, this deficiency being made good by the flowing back of some of the water which has accumulated in the reservoirs during the preceding night. In the night-time the converse holds good, the pumps forcing the surplus water into the reservoirs, and thus providing for the daily overdraft upon the rising main ; there is, in fact, a "tide" in the supply. The fact of our treatment being at both ends of the system (*i.e.*, at waterworks and at reservoirs) proportionately reduced the chances of pathogenic organisms escaping destruction.

Summary of results.

77·3 per cent. of the samples collected during a period of two months from the main tap at the waterworks, from main taps throughout the area of supply, and from the reservoirs (163 samples in all) contained no B. coli in 100 cubic centimetres.

17·7 per cent. contained B. coli in 100, but not in 10 cubic centimetres.

4·9 per cent. contained B. coli in 10, but not in 1 cubic centimetre.

These facts speak for themselves and comment is superfluous.

Innocuous nature of the treated water.

During the course of the treatment we understand that many statements have been made as to the deleterious character of the treated water. We should like to point out here that the "chlorine mixtures," prescribed by medical men in the treatment of the very disease (enteric fever) which it has been our object to prevent, excel in active strength anything that we have allowed to pass into consumption. The alleged action of the water upon sensitive skins is difficult to explain, as the treated water after filtration is not appreciably harder, and contains little more solid matter, and practically no more combined chlorine than the water before treatment. Probably in the earlier stages of the treatment, when a heavier dose had to be employed, minute traces of hyperchlorite remained in the water.

But we would again emphasize the fact that the taste and smell of the treated water are the result of the exhaustion of the "activity" of the germicidal agent in killing the bacteria and oxidising the organic matter of the water and the filter beds. It is not the taste and smell of the active agent itself which is perceived by the critical consumer.

It ought to be borne in mind that the choice in the present case lay between a treated water with this slight taste and smell, but harmless, and an untreated water which was palatable, but possibly charged with the morbific virus of enteric fever.

If the above argument commends itself to men holding positions of trust and responsibility in Lincoln, surely a general feeling of confidence in the water as now supplied to the city might be gradually brought about.

The question of boiling the water.

In our report, dated February 25th, we advised boiling the water as an additional precaution. The question has been raised why it should be desirable to boil the water if it has already been rendered innocuous by chemical treatment. We have not thought fit to withdraw the recommendation to boil the water, nor are we prepared unconditionally to do so now, though we believe it to be unnecessary, and to have been unnecessary for nearly two months. But in dealing with the water supply of over 50,000 people, living in the midst of a serious epidemic, alleged to be water borne, we have thought it better rather to overdo preventive recommendations than the reverse, and this although we had cumulative and convincing evidence of the harmless nature of the treated water.

Hence, although we have every reason to believe that boiling the water has been superfluous for some time past, we think that those who desire to make assurance doubly sure should continue the practice.

Personally, we have been drinking the water unboiled daily for over a month. The samples have been derived from the Waterworks, reservoirs, and taps all over the City.

Sources of Supply and Suggested Future Procedure.

Some misconception appears to exist with regard to the biological quality of the water of the Witham River. This river cannot be regarded as a suitable source of water supply, but the description of it as an open sewer is calculated to needlessly alarm the people of Lincoln. Our analyses show that the majority of samples are at least one million times purer bacteriologically than sewage. Excluding the pure Ballast Pit water and the relatively pure (bacteriologically) Hartsholme water, our results indicate that the Witham River is the least impure bacteriologically of the different sources of water supply.

The Catch-water Drain and Pike Drain, although unsatisfactory sources of water supply, are, nevertheless, at least ten thousand times purer bacteriologically than sewage.

We allude to these matters, not by way of extenuation of the continued use for water-works purposes of polluted water, or water liable to be polluted, but with the object of presenting the facts at our disposal in their true proportion and robbed of all prejudice and exaggeration.

We strongly approve of the action of the Corporation in seeking a new source of water supply. But until this new supply is available for distribution to the consumers, it seems unfortunate that the unhappy combination of circumstances which culminated in the present epidemic should be considered as necessarily attending the continued use of the existing supply. There is no precedent for such a gloomy prognostication; on the contrary, there is every reason to hope that the factors which have combined to create the epidemic are now dispersed. In this connection it should be borne in mind that the filtration area is now considerably greater than it was during the many years of comparative immunity from enteric fever which preceded the present epidemic.

Taking all the circumstances into account, we still recommend the continuance of the treatment in a modified form, although every week that passes probably tends to make it of less vital importance. But we have to remember that what has happened once may conceivably happen again, and we cannot, therefore, at this stage, advise that the treatment be stopped altogether. We have now reduced the dose of germicide to the lowest limit compatible with reasonable efficiency. When the new sand filter bed is in operation, and when finer sand has taken the place of the somewhat coarse sand now in use on some of the filter beds, the question of relying solely on filtration will require careful consideration.

In conclusion, we have the best reasons for believing that the treatment of the water has been a success bacteriologically; and, further, if we take into account the grave situation which rendered this treatment necessary, we think it has also been a success practically, in that it has produced a harmless and drinkable, though not quite tasteless, water.

We are, Gentlemen,

Yours faithfully,

A. C. HOUSTON.

GEORGE McGOWAN.

April 20th, 1905.

CARHOLME WARD

CASTLE WARD

MINSTER WARD

WITHAM WARD

ABBEY WARD

PARK WARD

MAP

SHOWING THE

CITY OF LINCOLN

AND NEIGHBOURHOOD.

Boundary of the City

City Wards

Bracebridge Urban District

Bracebridge Drainage Area

Special Area of New Boultham Parish

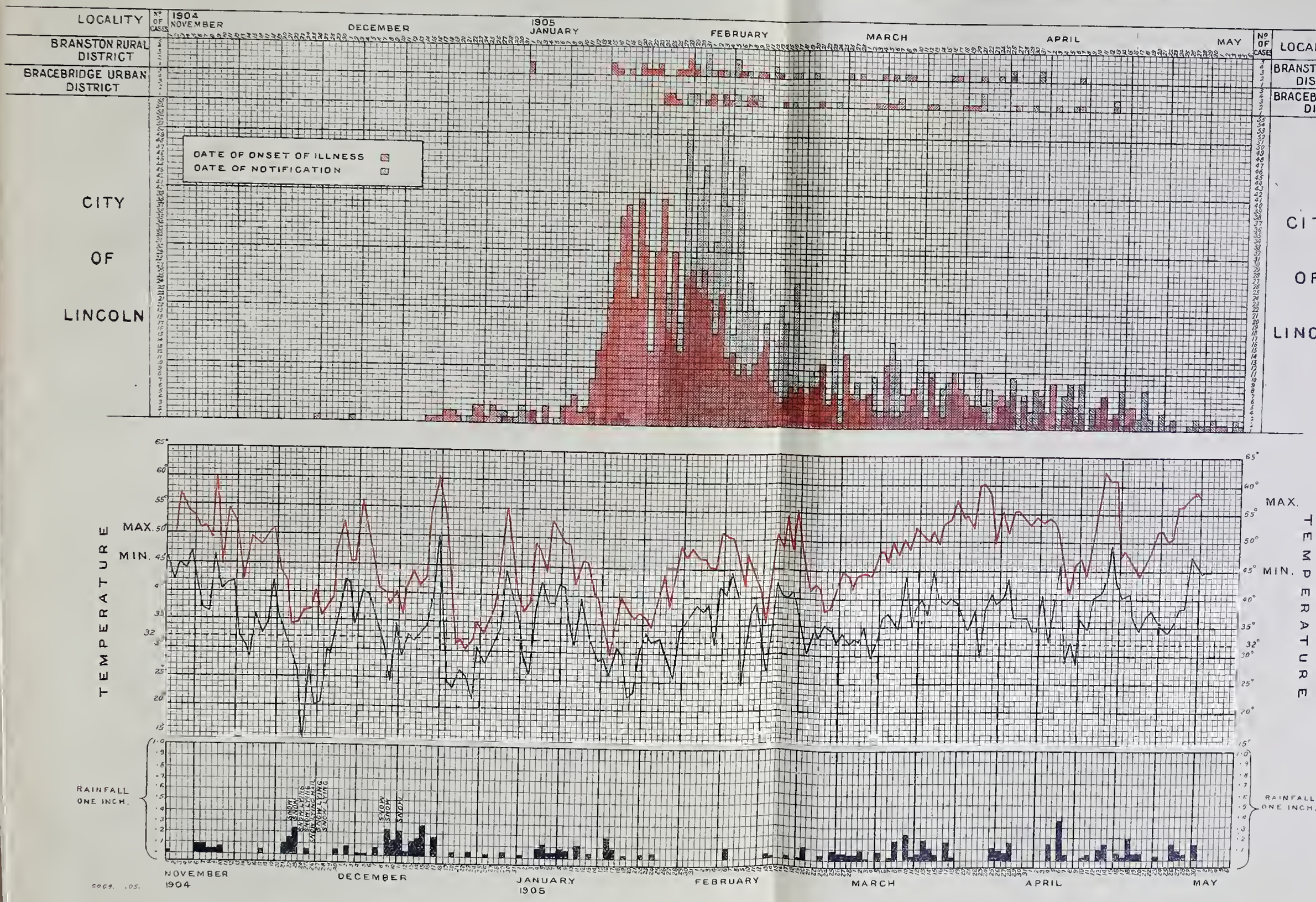
Contour Lines

Distribution of Enteric Fever from 2nd December, 1904, to 18th April, 1905.

Ordnance Survey Southampton

DIAGRAM I.

SHOWING FOR THE CITY OF LINCOLN AND THE BRACEBRIDGE URBAN AND THE BRANSTON RURAL DISTRICTS. THE DATE OF NOTIFICATION AND THE DATE OF ONSET OF THE ILNESS OF CASES OF ENTERIC FEVER FOR THE PERIOD 1ST NOVEMBER 1904 TO 6TH MAY 1905; TOGETHER WITH THE DAILY RANGE OF TEMPERATURE OF THE LOCALITY AS SHOWN BY THE MAXIMUM AND MINIMUM THERMOMETER AND THE RECORDED DAILY RAINFALL.



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